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CONTENTS

02 July 1990

BROADCASTING, CONSUMER ELECTRONICS

Measurement of Recombination Parameters of High-Efficiency Silicon Solar Cells by Contactless Microwave Method [Yu.A. Anoshin, V.M. Bazin, et al; GELIOTEKHNIKA No 5, Sep-Oct 89]	1
Performance Characteristics of Solar Battery Modules Built with Silicon Cells Graded According to Efficiency and Material Quality [A.K. Zaytseva, G.D. Naumova; GELIOTEKHNIKA No 5, Sep-Oct 89]	1
Determining Proper Resistance of External Switching Circuit for Solar Battery [A.Ye. Irodionov, V.A. Kurenkova, et al; GELIOTEKHNIKA No 5, Sep-Oct 89]	1
Calculation of Heat Sensor Temperature in Alternately Exposed and Shaded Sun Tracking System [N.V. Kolomojets, B. Nurgeldyyev, et al; GELIOTEKHNIKA No 5, Sep-Oct 89]	2
Concentrating Power of Cylindrical Solar Radiation Concentrators with Elastically Deformed Surface [L.M. Simanovskiy; GELIOTEKHNIKA No 5, Sep-Oct 89]	2
Results of Tests Performed on Automatic Control System for Heliostat Field in Crimean 5 MW Solar Electric Power Plant [S.V. Isayev, A.G. Kostyukovskiy; GELIOTEKHNIKA No 5, No 5, Sep-Oct 89] ...	2
Expected Energy Indicators of Experimental 5 MW Solar Electric Power Plant in Crimea [A.V. Treputnev; GELIOTEKHNIKA No 5, Sep-Oct 89]	3
Results of Prolonged Testing Done on Solar Array of AlGaAs Heterojunctions and Radiation Concentrators [Kh.K. Aripov, R.I. Isayev, et al; GELIOTEKHNIKA No 5, Sep-Oct 89]	3

ANTENNAS, PROPAGATION

Effect of Large-Scale Artificial Ionospheric Perturbations on Propagation of Short Radio Waves [V.A. Alimov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOFIZIKA Vol 32 No 7, Jul 89]	4
Theory of Formation of Resonance Structure of Atmospheric EM Background Noise within Range of Short-Period Geomagnetic Fluctuations [P.P. Belyayev, S.V. Polyakov, et al; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOFIZIKA Vol 32 No 7, Jul 89]	4
Lateral Propagation of Radio Waves along Short Meteor Radio Paths [T. Asiri, A.V. Karpov, et al; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOFIZIKA Vol 32 No 7, Jul 89]	4
Algorithm for Estimation of Space Coordinates Using Adaptive Antenna Array [M.M. Marder, M.N. Surkov; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOELEKTRONIKA Vol 32 No 8, Aug 89]	4
Maximum Entropy Method for Problems of Spectrum Analysis of Radio Navigation Signals [A.K. Bernyukov, T.A. Lutsenko; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOELEKTRONIKA Vol 32 No 8, Aug 89]	5
Reception of Optical Signal with Unknown Delay [A.P. Trifonov, T.M. Ovchinnikova; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOELEKTRONIKA Vol 32 No 8, Aug 89]	5
Decoding of Block Codes in Data Transmission Systems with Pseudorandom Frequency Switching [S.L. Portnov, S.B. Zhironkin; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOELEKTRONIKA Vol 32 No 8, Aug 89]	5
Fluctuations of Pulsed Laser Radiation during Thermal Self-Action in Turbulent Atmosphere [V.V. Vorobyev, T.G. Krasilnikova, et al; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOFIZIKA Vol 32 No 9, Sep 89]	5
Bleaching Effect and Radiation Transfer in Medium with Large-Scale Scatterer Concentration Fluctuations [N.I. Klorin, Yu.A. Kravtsov, et al; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOFIZIKA Vol 32 No 9, Sep 89]	6
Control of Small Phased Antenna Arrays to Given Amplitude-Phase Distribution [V.V. Ryapolov, V.M. Fidorenko; IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENII: RADIOFIZIKA Vol 32 No 9, Sep 89]	6

Mueller Matrix of Statistically Uneven Surface for Radar Waves [A.V. Belobrov, I.M. Fuks; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 10, Oct 89</i>]	6
Deformation of Wavefront of Sounding Radiation in Refraction Channel with Aberrations [I.P. Lukin; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 10, Oct 89</i>]	6
Emission of Electromagnetic Waves into Nonsteady Nonhomogeneous Magnetic Media [V.V. Kolesov; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 10, Oct 89</i>]	7
Amplification of Synoptic Vortices Localized in Lower Thermosphere [V.I. Petviashvili, N.V. Petviashvili, et al; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 11, Nov 89</i>]	7
Statistical Characteristics of Pulse Signal Polarization during Vertical Sounding of Ionosphere [A.G. Bronin, N.A. Zabolotin; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 11, Nov 89</i>]	7
Effect of Local Inhomogeneity in Ionosphere on Field of Vertical Magnetic Dipole [O.V. Solov'yev; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 11, Nov 89</i>]	8
Conditions for Self-Excitation of Gyrotron Taking into Account Space- Charge Effects [V.L. Bratman, A.V. Pylin; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 11, Nov 89</i>]	8

CIRCUITS, SYSTEMS

Radiation Temperature Characteristics of Mid-Atlantic Ocean Surface Based on Measurement Data [T.V. Aleksandrova, T.Ye. Barkan, et al; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 8, Aug 89</i>]	9
Diffraction of Electromagnetic Wave by Two Homogeneous Dielectric Bodies [Ye.N. Vasilyev, V.F. Makkaveyeva, et al; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 8, Aug 89</i>]	9
Adaptive Resolution of Coherent Signals during Random Motion of Source and Antenna [G.V. Serebryakov; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA Vol 32 No 8, Aug 89</i>]	9
Bilateral Sign Algorithm for Detection of Monochromatic Signals and Determination of Their Number [L.N. Kononov; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA Vol 32 No 9, Sep 89</i>]	10
Algorithm for Classification of Nonhomogeneous Signal-and-Noise Sample [I.G. Prokopenko; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA Vol 32 No 9, Sep 89</i>]	10
Comparative Evaluation of Interference Immunity of Mobile Radio Communication Systems with either Single-Sideband Modulation or Angle Modulation in Presence of both Additive and Multiplicative Interference [<i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA Vol 32, No 9, Sep 89</i>]	10
Space-Time Processing of Wideband Signals Mixed with Non-Gaussian Interference [O.I. Shelukhin, V.N. Kravchenko; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA Vol 32 No 9, Sep 89</i>]	10
Modeling of Surface-Acoustic-Wave Transducers with Internal Reflectors [Ye.A. Nelin; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA Vol 32 No 9, Sep 89</i>]	11
Parallel Data Transmission Based on Walsh Functions [V.A. Vershinin; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA Vol 32 No 9, Sep 89</i>]	11
Solution of Scattering Problem for Conducting Cylinder in Rectangular Waveguide [M.M. Ivanishin; <i>RADIOTEKHNIKA I ELEKTRONIKA Vol 34 No 8, Aug 89</i>]	11
Broadening of Spectral Line of Decimetric and Centimetric Radio Waves During Radio Communication with 'Venera-15,16' Spacecrafts through Circumsolar Plasma [A.I. Yefimov, O.I. Yakovlev, et al; <i>RADIOTEKHNIKA I ELEKTRONIKA Vol 34 No 8, Aug 89</i>]	11
Correlation Between Frequency Fluctuations of Radio Waves Propagating through Turbulent Atmosphere [N.A. Armand, Ye.A. Lobanov; <i>RADIOTEKHNIKA I ELEKTRONIKA Vol 34 No 8, Aug 89</i>]	12

Acoustooptic Demodulation of Differential-Phase-Shift Keyed Signals [V.S. Kulakov, Yu.I. Nikitin, et al; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 8, Aug 89]	12
Conditions for Existence of Long Surface Channels for Propagation of VHF Radio Waves [M.F. Zlotnikov, L.A. Olesov; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 8, Aug 89]	12
Field Plotting in Problems of Wave Diffraction at Bends of Rectangular Waveguide [V. M. Temnov; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	12
Experimental Studies Concerning Anomalies of Optical Wave and Radio Wave Diffraction at Large Zenith Distances [V. I. Sergiyenko, G. I. Modestova, et al.; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	13
Shift of Radio-Signal Carrier Frequency Within Region of Maximum Electron Concentration in Ionospheric Layer [N. I. Bushulkin, V. I. Zakharov, et al.; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	13
Efficiency of Adaptive Methods of Interference Direction Finding [O. P. Cheremisin; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	13
Processing of Radar Data in Measuring Systems from Standpoint of Group Theory [Yu. G. Bulychev and A. A. Korotun; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	14
Determination of Effective Frame Duration in Image Converter Tubes with Grid Shutter [V. P. Degtyareva, V. V. Ludikov, et al.; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	14
Attenuation of Centimetric Ground Waves Owing to Interference [V. N. Pozhidayev and A. V. Shabelnikov; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	14
Algorithms for Compensation of Ionospheric Error in Radio Altimeters [V. M. Pavlov and Yu. S. Rascheplyayev; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> , Vol 34 No 9, Sep 89]	14
Measurements of Size Distributions of Raindrops and Estimation of Attenuation Coefficients for Radio Waves [M.V. Zakharyan, L.N. Kornilov, et al; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 10, Oct 89]	15
Resolving Power Of Antennas in Anisotropic Medium [Ye.A. Lobanov, A.N. Lomakin; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 10, Oct 89]	15
Reflection of Electromagnetic Pulse by Parabolic Layer of Anisotropic Absorbing Plasma [V.K. Berger; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 10, Oct 89]	15
Radiation Pattern of Array of Convergent Wave Beams [N.P. Maryin; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 10, Oct 89]	15
Maximum-Likelihood Estimates of Form and Bearings of Linearly Independent Signals [A.M. Vagapov; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 10, Oct 89]	16
Synthesis of Frequency Characteristics of Spin Wave Devices Based on Antenna Arrays with Curvilinear Profile [V.F. Dmitriyev; <i>RADIOTEKHNIKA I ELEKTRONIKA</i> Vol 34 No 10, Oct 89]	16
Spatial Characteristics of Radar with Synthesized Aperture under Severe Limitation of Input Signals [K.G. Papushin, N.I. Neilo; <i>RADIOTEKHNIKA</i> No 9, Sep 89]	16
Derivative Signal Systems and Their Characteristics [<i>RADIOTEKHNIKA</i> No 9, Sep 89]	16
Energy Losses in Digital Receivers of Pseudonoise Signals [A.N. Bondarev, M.I. Zhadzishskiy, et al; <i>RADIOTEKHNIKA</i> No 9, Sep 89]	16
Interference Compensation during Detection of Signal with Random Amplitude and Initial Phase [<i>RADIOTEKHNIKA</i> No 9, Sep 89]	17
Dielectric Structures Supporting Reflector Antennas [T.L. Gruzinskaya, G.G. Tsurikov, et al; <i>RADIOTEKHNIKA</i> No 9, Sep 89]	17
Use of Digital Filtration for Decreasing Random Errors of Antenna Measuring Apparatus [R.I. Rumyantsev; <i>RADIOTEKHNIKA</i> No 9, Sep 89]	17
Semiconductor Memories Suitable for Microprocessor Systems [M.I. Maslov, V.V. Pavlov; <i>RADIOTEKHNIKA</i> No 9, Sep 89]	17
Automatic Phasing of Multichannel Output to Common Reference Signal [A.P. Pirkharka; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	18
Integrated-Circuit Version of Intermediate-Frequency FM Amplifier [A.V. Krivosheykin, M.G. Moshkovich; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	18
Model of Charge-Coupled Devices with Stepped Dielectric Layer [V.Ye. Prozorovskiy; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	18
Models of Electromagnetic Pulses from Lightning and from Electrostatic Discharge [K.V. Tuzov; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	18
Unbiased Digital Detector of Signals Mixed with Interference [L.N. Anisimova, A.P. Koldanov; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	18

Excitation of Elliptical Cylinder by Slot Antennas [V.A. Kravtsov, G.V. Kravtsova, et al; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	19
Effect of Beam Deviation from Geometrical Axis of Phased Antenna Array on Polarization Pattern of Transmitted and Received Signals [Ye.L. Kazako, Yu.A. Kavin; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	19
Method of Extracting Pulse Signal [I.F. Gavrilenko; <i>RADIOTEKHNIKA</i> No 10, Oct 89]	19
Some Results of Studies Pertaining to Long-Distance Tropospheric Radio Communication over Routes in Central European USSR [Ye.Ya. Marchenko, S.V. Fedorov, et al; <i>RADIOTEKHNIKA</i> No 11, Nov 89]	19
Radio Echo with More than Second Long Delays [A.G. Shliionskiy; <i>RADIOTEKHNIKA</i> No 11, Nov 89]	20
Calculation of Atmospheric Errors in Phased Radio Systems [Ye.F. Korolev; <i>RADIOTEKHNIKA</i> No 11, Nov 89]	20
Design of Wideband Microwave Switch [V.P. Petrenko; <i>RADIOTEKHNIKA</i> No 11, Nov 89]	20
Dimensioning of Modules for Antenna Array with Hexagonal Aperture [Ye.N. Korostyshevskiy, G.A. Polukhin; <i>RADIOTEKHNIKA</i> No 11, No 89]	21
Space Spectrum Analysis of Laser Scanner System Forming Remote Image [V.G. Shinkarenko, A.D. Karavayev; <i>RADIOTEKHNIKA</i> No 11, No 89]	21
First Soviet Studies of Antenna System Adaptation to Interference [Ya.D. Shirman, S.I. Krasnogorov, et al; <i>RADIOTEKHNIKA</i> No 11, Nov 89]	21

COMPUTERS

Algorithm of Search for Potentially Unreliable Spots in Conductor Network on Printed-Circuit Board [Ye.I. Mazur; <i>ELEKTRONNOYE MODELIROVANIYE</i> Vol 11 No 5, Sep-Oct 89]	22
Analysis and Optimal Design of Self-Diagnosing Systems [B. S. Stogniy, A. V. Kirilenko, et al.; <i>ELEKTRONNOYE MODELIROVANIYE</i> , Vol 11 No 6, Nov-Dec 89]	22
Software for Simulation in Diversity Radio Measurement Systems [V. P. Tkachenko; <i>ELEKTRONNOYE MODELIROVANIYE</i> , Vol 11 No 6, Nov-Dec 89]	22

MICROWAVE THEORY, TECHNIQUES

Noise in Millimetric-Wave Schottky-Barrier Mixer Diodes [S.A. Kravchuk, T.N. Narytnik, et al; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA</i> Vol 32 No 10, Oct 89]	23
Performance Characteristics of Detector Diodes in Microwave Controls [I.V. Lebedev, A.S. Shnitnikov; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA</i> Vol 32 No 10, Oct 89]	23
Hybrid Integrated Circuits for Balanced Shortwave Diode Mixers [S.A. Kravchuk, Yu.I. Yakimenko; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA</i> Vol 32 No 10, Oct 89]	23
Design Calculations for Bunching of Rotating Relativistic Electron Beam [D.M. Benevolenskiy, S.M. Movnin; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA</i> Vol 32 No 10, Oct 89]	23
Analytical Wave-Process Estimates for Microwave Vacuum Electron Devices [Yu.L. Bobrovskiy, S.R. Zarembskiy, et al; <i>IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA</i> Vol 32 No 10, Oct 89]	24

POWER ENGINEERING

Design Features and In-Service Inspection of 1150 kV Air Circuit Breakers [V.M. Lavrentyev, V.M. Plekhanov; <i>ELEKTROTEKHNIKA</i> No 10, Oct 89]	25
Technology and Equipment for Cold Rolling of Multistrand Cable with Ceramic Insulation in Variable-Profile Passes [V.V. Nosal, Yu.V. Rybakov, et al; <i>ELEKTROTEKHNIKA</i> No 10, Oct 89]	25
Ni-Zn Energy Sources for Electric Cars: Prospects of Improving Their Characteristics [V.Ye. Dmitrenko, V.V. Berendt, et al; <i>ELEKTROTEKHNIKA</i> No 10, Oct 89]	25

QUANTUM ELECTRONICS, ELECTRO-OPTICS

Space-Time Characteristics of Optical Signals in Raster-Type Data Transmission Systems [R.B. Shemshedinov, T.F. Kharisov; <i>OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST</i> May 89]	26
Law of Sines for Aperture Synthesis [V.A. Zverev; <i>OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST</i> No 5, May 89]	26

Polarization Modulator [V.N. Polyakov, V.K. Rezunkov; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST No 5, May 89]	26
Algorithm of Correlational Image Analysis for Automatic Focusing of Camera Objective [R.B. Mitkin; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST No 5, May 89]	26
Measurement of Optical Vector Field Characteristics by 'Polarization Interferometry' [A.L. Volpov, Yu.A. Zimin; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST No 11, Nov 89] ...	27
Spectral Characteristics of Two Solc Filter Variants [T.A. Vinogradova, A.A. Sidorenko; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST No 11, Nov 89]	27
Synthesis of Mirror-Type Radiation Energy Concentrators [R.A. Zakhidov; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST No 11, Nov 89]	27
Transformation of Gaussian Beam by Means of Circular Centered Diaphragm [S.I. Molkov, T.V. Shelyakova; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST No 11, Nov 89]	28
Computer-Aided Design of Technological Processes for Manufacture of Optical Elements [S.I. Lelyukhin, A.v. Yegorov; OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST No 11, Nov 89] ..	28

SOLID STATE CIRCUITS

Optimization Method of Simulating Electron-Beam Lithography Processes [K.A. Valiyev, A.N. Kirillov, et al; MIKROELEKTRONIKA Vol 18 No 6, Nov-Dec 89]	29
Prospects of Using Method of Laser Pyrolysis for Fabrication of Micro- electronic Structures and Status of Its Development [L.A. Ryabova, V.S. Salun, et al; MIKROELEKTRONIKA Vol 18 No 6, Nov-Dec 89]	29
Accelerator Hardware for Faster Modeling of VLSI Circuits [B.G. Sergeev; MIKROELEKTRONIKA Vol 18 No 6, Nov-Dec 89]	29

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Measurement of Recombination Parameters of High-Efficiency Silicon Solar Cells by Contactless Microwave Method

907K0092A Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 89 (manuscript received 6 Dec 87) pp 3-8

[Article by Yu.A. Anoshin, V.M. Bazin, and A.S. Darevskiy, All-Union "Order of Labor's Red Banner" Scientific Research Institute of Current Sources]

[Abstract] A contactless modulation method has been developed for measuring the recombination parameters of Si solar cells at a microwave frequency (10 GHz) rather than at a high frequency (11 MHz) so as to ensure a higher sensitivity, the purpose of such measurements being design optimization for maximum efficiency. The instrument, a cylindrical cavity resonator excited by a Gunn oscillator, has been designed for n^+p-p^+ , n^+p-n^+ , p^+p-p^+ structures as well as solar cells with base regions covering the 4.5-45 ohm.cm range of electrical resistivity. In solar cells with a n^+p-p^+ structure both I_{0n^+} and I_{0p^+} saturation current densities in the doped n^+ and p^+ regions were found not to exceed 10^{-2} nA/cm², the diffusion length for excess electrons in the p-base being not larger than the base width. The method was tested on two solar cells, their respectively 245 mm and 275 mm wide base regions having equal electrical resistivities of approximately 25 ohm.cm equal short-circuit current densities with unilateral amplitude modulation, but their equilibrium hole concentrations p_0 were 6.6×10^{14} cm⁻³ and 5.9×10^{14} cm⁻³ respectively. Mean steady-state electron concentration n_s , ratio n_s/p_0 , short-circuit current density, open-circuit voltage, and bulk lifetime of excess electrons in the p-base were measured over the 8-260 mW/cm² range of illuminance. In order to separate the contributions of n^+ regions and p^+ regions to the total recombination loss, symmetric n^+p-n^+ and p^+p-p^+ structures were tested over the 0.66-14.2 nA/cm² range of the I_{0p} current density. Figures 2; tables 2; references 5.

UDC 621.472:621.383.2

Performance Characteristics of Solar Battery Modules Built with Silicon Cells Graded According to Efficiency and Material Quality

907K0092B Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 89 (manuscript received 8 Sep 87)
pp 8-13

[Article by A.K. Zaytseva and G.D. Naumova, All-Union "Order of Labor's Red Banner" Scientific Research Institute of Current Sources]

[Abstract] Considering that the current-voltage characteristics of identically built solar batteries can differ depending on the operating temperature and the efficiency of their cells, while the efficiency of identically produced silicon solar cells in turn depends on the grade

of silicon, an experimental study of this problem was made using two lots of solar cells produced each with a different grade of p-Si single crystals grown all by the Czochralski method along the (111)-axis. Those of one lot were produced from low-resistivity silicon, 1-2 ohm.cm, with a 7-15 μ s lifetime of minority carriers. Those of the other lot were produced from high-resistivity silicon, 20-30 ohm.cm, with a longer 20-70 μ s lifetime of minority carriers. All cells were doped so as to acquire an n^+p-p^+ structure. For the purpose of grading the solar cells in each lot according to efficiency, their load current was measured at the nominal voltage of 0.4 V under an S-6 luminaire containing an array of halide lamps with a color temperature within the 3050-3150 K range. The cells sorted for connection into series-parallel modules and, for a comparative evaluation of the current-voltage characteristics of the modules, their load currents were measured at several voltage levels ranging from open circuit (zero current) to short circuit at three typical operating temperatures: 50°C, 60°C, and 75°C. Figures 2; references 5.

UDC 621.472:621.3.017.2

Determining Proper Resistance of External Switching Circuit for Solar Battery

907K0092C Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 89 (manuscript received 23 Feb 87)
pp 16-18

[Article by A.Ye. Irodionov, V.A. Kurenkova, V.N. Potapov, and D.S. Strebkov, All-Union Scientific Research Institute of Electrification of Agriculture]

[Abstract] The proper resistance of the external switching circuit for a solar battery is determined by superposing on the current-voltage characteristic of the battery those of the blocking diode and the connecting cable, the voltage drop across the two being particularly significant in the case of a low-voltage cell. Into consideration is taken the fact that a solar battery delivers maximum power at some optimum voltage, the latter depending on the battery temperature T and on the battery insolation Q (operating temperature $T = 40^\circ\text{C}$ and $Q = 1 \text{ kW/m}^2$ standard in the USSR). Inasmuch as the optimum voltage accordingly changes with changing temperature and illumination, it will not always be the operating voltage and the efficiency of the battery will then drop below the maximum attainable. The dependence of the optimum voltage V_{opt} and of its instability $[\max V_{\text{opt}}(Q) - \min V_{\text{opt}}(Q)]/V_{\text{std}} = F(R_{\text{ext}}/R_0, T_{\text{amb}})$ (R_0 - battery resistance under standard operating voltage and load, R_{ext} - diode and cable resistance, T_{amb} - ambient temperature) is evaluated by semiempirical and numerical methods, because not only coefficients K_T and K_Q in the relation $V_{\text{opt}}(T, Q) = V_{\text{std}}(T_{\text{std}}, Q_{\text{std}})K_TK_Q$ are empirical functions of T and Q respectively but also F is not an analytic function of R_{ext}/R_0 and T_{amb} . Calculations reveal that there is a range of ratio R_{ext}/R_0 values which should be avoided. Figures 2; references 1.

UDC 662.997

Calculation of Heat Sensor Temperature in Alternately Exposed and Shaded Sun Tracking System*907K0092 Tashkent GELIOTEKHNIKA in Russian No 5, Sep-Oct 89 (manuscript received 2 Nov 87) pp 28-30*

[Article by N.V. Kolomojets, B. Nurgeldyyev, Z.M. Dashevskiy, A. Charykulyev, Yu.I. Shmatok, and A.G. Komarov, All-Union 'Order of Labor's Red Banner' Scientific Research Institute of Current Sources]

[Abstract] A sun tracking system is considered with a pair of identical cantilever bimetal strips fastened to the shaft of a ratchet wheel so that the teeth of the latter are within the reach of both strips at their free ends the shaft being oriented parallel to the world axis. This device is surrounded by a coaxial cylindrical shield, a hoop consisting of a number of identically wide transparent segments interleaved by identical narrower opaque segments so that the strips are alternately exposed to and shaded from sun light as the sun "moves" across the sky. The temperature of the strips correspondingly changes in the process at a rate depending on the speed of Earth rotation about its axis so that the strips alternately deflect when hot and flatten when cold, thus setting the ratched wheel in motion as they bear on its teeth. The rotation of the shaft is transmitted to the heliostat. As the key to a design and performance analysis of such a tracking system, the temperature of a strip in this configuration is calculated accordingly as a periodically varying function of time with an amplitude that depends not only on the widths of transparent and opaque shield segments as well as on the strip material and the strip dimensions but also on the integral heat transfer coefficient and thus also on the ambient temperature. Figures 2; references 5.

UDC 662.997:537.22(088)

Concentrating Power of Cylindrical Solar Radiation Concentrators with Elastically Deformed Surface*907K0092E Tashkent GELIOTEKHNIKA in Russian No 5, Sep-Oct 89 (manuscript received 17 Apr 87) pp 31-33*

[Article by L.M. Simanovskiy, All-Union 'Order of Labor's Red Banner' Scientific Research Institute of Current Sources]

[Abstract] Shape optimization of a solar radiation concentrator made of sheet material with a reflecting surface is considered, the object being to most closely approach a parabolic cylinder. This is done by elastically deforming the sheet with two orthogonal forces and a moment applied to each of two opposite edges. Analytically the problem is tackled by first assuming parallel incident rays and calculating the concentration coefficient for the final reflector surface, then maximizing that

coefficient by varying the forces and the moment with the actual divergence of sun rays taken into account. The corresponding Cauchy problem has been solved numerically by the Runge-Kutta method for two cases: 1) forces and moment perpendicular to the entrance window, 2) forces and moment parallel to the entrance window. The the heat collector was in each case assumed to either be flat or have the shape of a circular cylinder, with no thermal insulation around the shaded part of the heat exchanger. Figures 1; references 3.

UDC 62-50:662.997(088.8)

Results of Tests Performed on Automatic Control System for Heliostat Field in Crimean 5 MW Solar Electric Power Plant*907K0092F Tashkent GELIOTEKHNIKA in Russian No 5, Sep-Oct 89 (manuscript received 11 Apr 88) pp 36-40*

[Article by S.V. Isayev and A.G. Kostyukovskiy, All-Union Scientific Research Institute of Heat Engineering imeni F.E. Dzerzhinskiy, Western branch]

[Abstract] The automatic control system for the heliostat field in the Crimean 5 MW solar electric power plant was tested under radiation densities of 320-540 W/m² and at wind velocities of 4-8 m/s, this system having been decentralized by stagewise delegating the control function to local automation subsystems. Each heliostat is driven by a Sh-2.65/50-01 stepper motor in a zenithal-azimuthal mount. Normal tracking is done through optical 2-coordinate transducers and contactless limit switches, the eight stepper motors being energized through optron commutators which form a reversible 4-phase power distribution network with time division of channels. Control is applied to the direction of reflected sun rays relative to the direction of the optical transducer vector, the angle between them being a measure of the error, and the normal to a heliostat surface is determined by the coordinate of the load end of the heliostat drive. The purpose of the tests was to determine the dependence of the delay time on the number of heliostats covered by one local control subsystem and to determine the allowable number of heliostats that can be controlled by one computer, this number depending on the dynamic characteristics of the heliostat drives. The results of a theoretical stability analysis on the basis of the Nyquist amplitude-phase criterion most convenient for linear structures with time delay were corrected, on the basis of the test results and their extrapolation, for nonlinearities in the subsystems including the relay-type transfer function with an insensitivity zone of optical transducers, the hysteresis introduced by phase generators and computer programs, and the finite speed range of stepper motors, their maximum speed not depending on the computer speed and thus on the signal processing time. Typically, a time delay of 6 s was found to be the critical one for heliostat having a time constant of 4 s and

a drive with a 0.88 s^{-1} ratio of usable power gain to control time constant at a reference speed of $100^\circ/\text{h}$. Figures 2; references 6.

UDC 662.997

Expected Energy Indicators of Experimental 5 MW Solar Electric Power Plant in Crimea

907K0092G Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 89 (manuscript received 12 Apr 88)
pp 40-46

[Article by A.V. Treputnev, All-Union Scientific Research Institute of Electrification of Agriculture]

[Abstract] For the purpose of optimizing the operation of the experimental 5 MW tower-type solar electric power plant in Crimea, its energy indicators are evaluated on the basis of a theoretical analysis applicable to real ambient conditions and given system design parameters. The key energy indicators are average annual and maximum daily solar energy reflected by the heliostat field into the steam generator, both depending essentially on the intake of directly incident solar radiation and on the reflection coefficient of the collector mirrors. Specifications call for a 0.8 or higher integral spectral reflection coefficient, but only 0.75 has been anticipated in the design calculations and only 0.7 (0.68-0.72) has been attained with available glass manufacturing technology. Extrapolation of the data according to a semi-empirically constructed algorithm and comparison with the performance of four other tower-type solar electric power plants (2.5 MW "Themis" in France, 1.0 MW "Eurelios" in Italy, 10.0 MW "Solar-1" in the U.S., 1.0 MW "Sunshine" in Japan) indicate how to operate the Crimean one optimally and also most economically. Figure 4; references 3.

UDC 621.362:537.215

Results of Prolonged Testing Done on Solar Array of AlGaAs Heterojunctions and Radiation Concentrators

907K0092H Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 89 (manuscript received 20 Sep 88)
pp 81-83

[Article by Kh.K. Aripov, R.I. Isayev, B.M. Makhkamdzhanov, M.S. Mansurov, V.D. Rumyantsev, and S.A. Ustinov, Tashkent Institute of Electrical Communications Engineering]

[Abstract] A solar array of AlGaAs heterojunctions and radiation concentrators for applications such as an independent power source in unattended communication equipment was tested in the mountains of the UzSSR over two successive summer periods (June-July-August) 1987 and 1988. The array, eight identical modules connected in series, had been installed at 800 m altitude above sea level. Its current-voltage characteristic was measured during a clear day ahead of time and its performance parameters measured at that time served later as reference for subsequent evaluation of the test results. In addition to the current-voltage characteristic under the heat load were also measured and recorded incoming solar radiation energy, power output, and discharge current. The heterojunctions and the Fresnel lenses were periodically inspected for maintenance. The results of these tests indicate a need for better soldering the heterojunction so as to prevent their cracking and for better hermetization of their surfaces so as to prevent oxidation. It is advisable to produce the Fresnel lenses by the polymerization process and that they be automatically cleaned in service during operation of the solar array. Figures 3; references 6.

UDC 621.371.25

Effect of Large-Scale Artificial Ionospheric Perturbations on Propagation of Short Radio Waves

907K0032A Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENII: RADIOFIZIKA
in Russian Vol 32, No 7, Jul 89 (manuscript received
22 Sep 87) pp 795-801

[Article by V.A. Alimov, Scientific Research Institute of Radiophysics]

[Abstract] Propagation of short radio waves through an artificially perturbed region of the ionosphere is analyzed on the basis of two models, the first model of such a region being an isolated regular large-scale inhomogeneity in terms of electron concentration and the second one being an isolated turbulence region. The effect of a perturbation on the statistical characteristics of fluctuating short-wave radiation is in each case estimated theoretically by solving the corresponding two-dimensional problem for an incident radiation with an angular spectrum much narrower or much wider than the angular width of the main part of the inhomogeneity. A comparison of the results with available experimental data indicates that only the second model is adequate is adequate, confirming that a region of artificial turbulence produced by heating with powerful short-wave radiation does not appreciably influence the propagation of short radio waves through it. Figures 1; references 10.

UDC 550.388.3

Theory of Formation of Resonance Structure of Atmospheric EM Background Noise within Range of Short-Period Geomagnetic Fluctuations

907K0032B Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENII: RADIOFIZIKA
in Russian Vol 32, No 7, Jul 89 (manuscript received
23 Oct 87 after revision 20 May 88) pp 802-810

[Article by P.P. Belyayev, S.V. Polyakov, V.O. Rapoport, and V.Yu. Trakhtengerts, Scientific Research Institute of Radiophysics]

[Abstract] A theory of formation of the resonance structure in the spectrum of ELF (0.1-10 Hz) atmospheric electromagnetic noise is constructed, this frequency range corresponding to that of short-period geomagnetic fluctuations. It is based on the theory of propagation of ELF electromagnetic waves through a medium which includes three regions where the laws of geometric optics are violated: at the Earth surface, in the lower ionosphere, and in the F-layer above the electron concentration peak. Two more resonators in addition to the cavity between Earth and ionosphere are considered accordingly, namely the ionospheric Alfvén resonator and the ionospheric magnetoacoustic one. All three are first

treated as plane-parallel waveguides in a vertical magnetic. The planetary distribution of the tangential component of the magnetic field generated by a vertical lightning discharge is subsequently calculated on the basis of a spherically symmetric model, in the approximation of an ideally conducting Earth, the frequency dependence of the admittance of the ionosphere being found to be responsible for formation of a resonance structure when oscillations are excited in the Alfvén resonator. Available experimental data can be adequately interpreted on the basis of this theory. References 10.

Lateral Propagation of Radio Waves along Short Meteor Radio Paths

907K0032C Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENII: RADIOFIZIKA
in Russian Vol 32, No 7, Jul 89 (manuscript received
22 Mar 88) pp 912-913

[Article by T. Asiri, A.V. Karpov, A. Kodirov, D. Latonov, V.I. Popov, L.N. Rubtsov, and M. Sharipov, Kazan State University]

[Abstract] Following earlier experiments with horizontally polarized antennas on the about 250 km long Dushanbe-Leninabad route for a study of meteor radio wave propagation along short paths over mountainous terrain, similar experiments were performed in the 1985-86 period with vertically polarized antennas on the same route and in 1987 again with horizontally polarized antennas on the about 100 km long Leninabad-Vorukh route. Fewer reflections of meteor radio waves were recorded with vertically polarized antennas and along the shorter route. The data agree with calculations based on the model of a tapering meteoric zone of the ionosphere useful for radio communication. Figures 2; references 2.

UDC 621.396.677.3:621.3.01

Algorithm for Estimation of Space Coordinates Using Adaptive Antenna Array

907K0047A Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENII: RADIOELEKTRONIKA
in Russian Vol 32, No 8, Aug 89 (manuscript received,
after revision, 28 Mar 88) pp 7-11

[Article by M.M. Marder and M.N. Surkov]

[Abstract] An algorithm is proposed for tuning an adaptive antenna array on the basis of a direct relation between the readings of its weight function and the space coordinates of radiation sources. It is demonstrated on an input process such as an additive mixture of echo signals from P bright point targets and a background interference in the form of a white noise. The covariance matrix of this input process is calculated as the sum of its respective components rather than being estimated first, which eliminates the errors arising in its preliminary estimation. The efficiency criterion for this

algorithm is minimum antenna output power, a compensator seeking the optimum vector of weight coefficients which will satisfy this criterion. References 4.

UDC 621.396.93

Maximum Entropy Method for Problems of Spectrum Analysis of Radio Navigation Signals

907K0047C Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 8, Aug 89 (manuscript received 23 Nov 87) pp 20-24

[Article by A.K. Bernyukov and T.A. Lutsenko]

[Abstract] Spectrum analysis of radio navigation signals by the maximum entropy method is considered, inasmuch as echo signals from targets with distributed and random structure are known to be describable in the form of second-order or third-order autoregressive series. No experimental data are, however, available regarding the adequacy of estimates made by this method and the dependence of their accuracy on the length of such a series, while available data regarding the resolution of spectrum analysis by this method and the dependence of its reliability on the signal-to-noise ratio are insufficient for conclusive validation. The method has, therefore, been tested in five relevant ways: 1) by comparing it with the Fourier method for truncated realizations of discrete random processes, 2) by determining the dependence of an estimate of spectral density on the length of the realization of a random process, 3) by estimating the spectral density of noisy harmonic signals, 4) by determining the frequency resolution of this method, 5) by estimating the spectral density of a radio navigation signal $u_2 = U \text{sinc}[2\pi F_0(n - N/2)T]$ used in systems with scanning radiation patterns of the radio beacons. The results of computer-aided calculations indicate that this method is quite effective and, in the case of short realizations of random and regular processes, the only feasible one. Figures 5; references 7.

UDC 621.391.63

Reception of Optical Signal with Unknown Delay

907K0047D Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA Vol 32, No 8, Aug 89 (manuscript received 4 Apr 88) pp 24-29

[Article by A.P. Trifonov and T.M. Ovchinnikova]

[Abstract] A common problem in optical communication and optical radar, namely reception of an optical signal with unknown delay, is solved with a maximum-likelihood receiver. Realization of a Poisson process is assumed to appear at the detector within a time interval from $-T/2$ to $T/2$ both in presence or absence of the optical signal. The probability of detector errors, including anomalous ones, is estimated on the basis of statistical simulation in the local-Markov approximation. The detection threshold is

calculated in accordance with the Neyman-Pearson criterion, whereupon the time delay is also estimated. These theoretical characteristics of the appropriate maximum-likelihood receiver agree asymptotically close with experimental data over a wide range of the signal-to-background ratio. Figures 4; references 7.

UDC 621.391.3

Decoding of Block Codes in Data Transmission Systems with Pseudorandom Frequency Switching

907K0047E Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 8, Aug 89 (manuscript received 1 Feb 88) pp 53-56

[Article by S.L. Portnov and S.B. Zhironkin]

[Abstract] Decoding of block codes in coherent data transmission systems which use pseudorandom frequency switching and error-correcting codes is considered, a new algorithm being proposed which utilizes properties of the projective plane and involves permutative decoding of soft solutions. It is demonstrated on the Reed-Solomon code and compared with the maximum likelihood decoding algorithm as well as with near optimum algorithms of decoding stiff solutions. It is shown to increase the stability of such data transmission systems in the presence of worst-case interference to a level approaching their stability in the presence of white noise. The algorithm is rather simple to implement with appropriate hardware. Figures 1; references 3.

UDC 621.373.826

Fluctuations of Pulsed Laser Radiation during Thermal Self-Action in Turbulent Atmosphere

907K0042A Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 9, Sep 89 (manuscript received 1 Feb 88) pp 1063-1071

[Article by V.V. Vorobyev, T.G. Krasilnikova, and N.S. Tikhonova, Institute of Atmospheric Physics, USSR Academy of Sciences]

[Abstract] Amplitude and phase fluctuations of pulsed laser radiation heating a turbulent atmosphere while propagating through it are calculated in the approximation of smooth perturbations, on the premise that the duration of a laser pulse is much longer than the time for sound to travel across the laser beam but much shorter than the characteristic time of atmospheric turbulence and that the laser beam is much wider than the scale of atmospheric turbulence. Losses of energy due to absorption and scattering are assumed to be small. Calculations involve numerical solution of the equations for the spectral components of both amplitude and phase fluctuations, taking asymptotically into account the effect of diffraction. The results indicate that thermal action of laser radiation on the medium causes its refractive index to fluctuate, which in turn alters the fluctuation spectra of the laser radiation

by attenuating its large-scale fluctuations while amplifying its small-scale fluctuations but narrowing their space-frequency range. Thermal nonlinearity also alters the structure of laser radiation fluctuations by first decreasing and then increasing their energy at radii smaller than width of the Fresnel zone. There the dispersion of amplitude fluctuations decreases and the coherence increases as a result, but more appreciably on short paths than on long ones. Figures 7; references 8.

UDC 535.33

Bleaching Effect and Radiation Transfer in Medium with Large-Scale Scatterer Concentration Fluctuations

907K0042B Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 9, Sep 89 (manuscript received 30 Dec 87) pp 1072-1078

[Article by N.I. Klorin, Yu.A. Kravtsov, A.Ye. Mereminskiy, and V.G. Mirovskiy, Moscow State Pedagogical Institute imeni V.I. Lenin]

[Abstract] A medium with fluctuating concentration of scatterers is considered and the effect of such fluctuations on radiation transfer is analyzed, the fluctuation scale becoming the third essential parameter in addition to the overall thickness of the medium and the characteristic dimension of the scatterers. Intrinsic thermal radiation in the medium is first disregarded for preliminary simplification of the problem, whereupon it is included in the equation of radiation transfer. Solution of that equation reveals a bleaching effect of large-scale scatterer concentration fluctuations, namely an attenuation of radiation absorption where the albedo is small and an attenuation of radiation scattering where the albedo is large. References 5.

UDC 621.396.674

Control of Small Phased Antenna Arrays to Given Amplitude-Phase Distribution

907K0042D Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 9, Sep 89 (manuscript received 27 Nov 87, after revision 31 May 88) pp 1132-1136

[Article by V.V. Ryapolov and V.M. Fidorenko]

[Abstract] Control of a small phased antenna array for realization of a given amplitude-phase distribution is considered, taking into account interaction of the few radiators but assuming lossless reciprocal phase shifters with ideally matched inputs. Iterative numerical calculations for linear equidistant arrays of parallel infinitesimally thin radiators, typically one of 0.469γ long radiators spaced 0.62γ apart (γ -wavelength in free space), have yielded the error of antenna beam setting as a function of the scan angle. The results indicate a linear current distribution but a nonlinear phase lead distribution over the array, the deviation of the latter from

linearity reaching 40° as the scan angle reaches 25° . Simultaneous amplitude and phase control of the radiator currents thus evidently requires a power supply with a variable-ratio power division, the ratio changing with change of the scan angle. Figures 1; references 2.

UDC 537.874.2

Mueller Matrix of Statistically Uneven Surface for Radar Waves

907K0076A Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 10, Oct 89 (manuscript received 13 Jan 88) pp 1232-1237

[Article by A.V. Belobrov and I.M. Fuks, Institute of Radio Astronomy UkSSR Academy of Sciences]

[Abstract] For a theoretical analysis of the scattering characteristics of rough surfaces in directions far from that of specular reflection, the Mueller matrix relating the Stokes parameters of the scattered field to those of the incident one is constructed for a statistically uneven plane surface which scatters an incident electromagnetic wave. This matrix is shown to determine the polarizing characteristics of a statistically uneven plane surface, namely the specific effective scattering area and the degree of polarization P of the scattered waves. First is considered a plain weakly rough surface, then the two-scale model which represents a scattering surface as the superposition of smoothed one and a microrough one. Numerical calculations of $(1-P)/\langle\gamma_x^2\rangle$ (dispersion of slopes) as function of the incidence angle have been made for asphalt, concrete, fresh-water (9°C), and metal surfaces quasi-specularly and diffusely scattering radio waves within the 34-135 GHz frequency range. Figures 2; references 6.

UDC 534.222

Deformation of Wavefront of Sounding Radiation in Refraction Channel with Aberrations

907K0076C Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 10, Oct 89 (manuscript received 14 Jan 88, after completion 5 Oct 88) pp 1258-1264

[Article by I.P. Lukin, Institute of Atmospheric Optics, Siberian Department, USSR Academy of Sciences]

[Abstract] The structure of a sounding beam of high-intensity optical radiation passing through a refraction channel with distorting aberrations is analyzed theoretically in the paraxial approximation of geometrical optics. The analysis is based on the vector equation for a geometrical radiation beam in a channel containing a medium with a slightly nonparabolic aberrational profile of the refractive index, a special case being a cylindrical one with uniform focal length and aberration along its optical axis. The trajectories of sounding radiation rays and the statistical characteristics of their phase are calculated with the aid of the eikonal equation. The analytical solution for an initially plane wavefront and numerical calculations for

atmospheric channels indicate the limits of validity not only for the paraxial approximation of geometric optics but also for both aberrationless and weak-aberration approximations. Figures 4; references 16.

UDC 537.87

Emission of Electromagnetic Waves into Nonsteady Nonhomogeneous Magnetic Media

907K0076D Gorkiy IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 10, Oct 89 (manuscript received 18 Jan 88, after collation 2 Feb 89) pp 1275-1284

[Article by V.V. Kolesov, Moscow Institute of Radio Engineering, Electronics, and Automation]

[Abstract] The perturbation method of calculating the characteristics of radiation emitted into a dielectric medium whose permittivity varies slightly in time and in space is extended to an analogously nonsteady nonhomogeneous magnetic medium, on the basis of the system of Maxwell equations for a medium having a dielectric permittivity $\epsilon = 1$ and a magnetic permeability $\mu = \mu_0 + \mu_1(r, t)$ where $\mu_1 \gg \mu_0$. Only the linear terms are retained here, and the expression for the Poynting vector is assumed to be same as for a medium with $\mu = 1$ and $\epsilon = \epsilon_0 + \epsilon_1(r, t)$ where $\epsilon_1 \gg \epsilon_0$. The radiation energy emitted per unit time by a magnetic dipole and the radiation energy emitted per unit length by a straight current filament and by a helical one are calculated accordingly, the frequency spectrum and the angular distribution in each case being obtained with the aid of a Fourier transformation and on the basis of the δ -function respectively. The type of polarization of radiation emitted by these sources into slightly nonsteady and/or slightly nonhomogeneous media is determined on the basis of the corresponding perturbation equation. The author thanks V.A. Davydov for stimulation and support of the study, B.M. Bolotovskiy, S.N. Stolyarov, and A.I. Plis for fruitful discussion of the results. References 14.

UDC 551.465.11

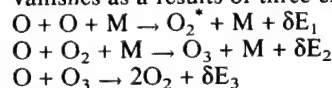
Amplification of Synoptic Vortices Localized in Lower Thermosphere

907K0087A Gorkiy IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 11, Nov 89 (manuscript received 17 Mar 88) pp 1315-1319

[Article by V.I. Petviashvili, N.V. Petviashvili, and A.Ya. Feldshteyn, Interdepartmental Committee on Geophysics, USSR Academy of Sciences]

[Abstract] Three-dimensional synoptic vortex-soliton formations are amplifiable by chemical energy stored in the lower thermosphere are constructed analytically, considering that the motion of neutral particles within the lower thermosphere is quite accurately described by equations of hydrodynamics which include six parameters influencing the wind velocity distribution and its kinetics: Coriolis

frequency, Brunt-Vaisala frequency, acoustic velocity, Rossby drift velocity, Rossby radius, and atmospheric altitude scale. A series expansion of these equations into powers of small parameters yields an equation which describes the evolution of generalized vorticity, one of its steady-state solutions being a three-dimensional vortex-soliton which can move eastward or westward. Its behavior and energy relations in the lower thermosphere is analyzed semiquantitatively, on the basis of the known fact that at 70-100 km altitudes excess atomic oxygen is produced and part of the solar energy is stored owing to photodissociation of molecular oxygen and that atomic oxygen then vanishes as a result of three exothermic reactions:



where M denotes any neutral particle, O_2^* denotes excited state of molecular oxygen (its relaxation attended by emission of 55.7.7 nm green radiation), $\delta E_1 = 5.1$ eV, $\delta E_2 = 1.0$ eV, $\delta E_3 = 3.9$ eV. The source of such solitons in the ionospheric D-layer has not yet been established, but a nonuniform velocity profile of neutral phonon wind and typhoons in the lower atmosphere are considered to be among the likely ones. The authors thank L.M. Yerukhimov, G.S. Ivanov-Kholodnyy, and B.S. Ryabov for helpful discussions. Figures 2; references 8.

UDC 550.338.2

Statistical Characteristics of Pulse Signal Polarization during Vertical Sounding of Ionosphere

907K0087B Gorkiy IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 11, Nov 89 (manuscript received 26 Jan 88) pp 1327-1333

[Article by A.G. Bronin and N.A. Zabolotin, Scientific Research Institute of Physics at Rostov University]

[Abstract] Vertical sounding of the ionosphere with radio pulse signals is examined from the statistical standpoint, concerning particularly the variation of their polarization parameters due to scattering in this randomly nonhomogeneous medium. Two parameters of the polarization ellipse, the angle which describes its ellipticity and the inclination angle of its major semiaxis, are defined in terms of Stokes parameters and their statistical characteristics are first calculated for the electric field of an electromagnetic wave in a linear collisionless magnetically active plasma in which such a field can be represented as the of a regular normal, ordinary or extraordinary, wave and a array of scattered ones of both kinds. Calculations are made in the single-scattering approximation, assuming a uniform and isotropic space distribution of random electron concentration irregularities and an inverse fourth-power irregularity spectrum. Sounding radio pulse signals and the statistical characteristics of their polarization ellipse are considered next, absorption of scattered waves being negligible only when scattering is nearly normal but their

refraction being significant unless the wave frequency is much higher than the plasma frequency. The dispersions of both polarization ellipse parameters are evaluated numerically for 2-5 MHz radio pulse signals of 25 μ s duration in a 1 km wide plasma layer at 100 km altitude. The authors thank V.D. Gusev, L.M. Yerukhimov, and P.F. Denisenko for discussion and helpful comments. Tables 1; references 24.

UDC 538.566

Effect of Local Inhomogeneity in Ionosphere on Field of Vertical Magnetic Dipole

907K0087C Gorkiy IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 11, Nov 89 (manuscript received 4 Apr 88) pp 1335-1342

[Article by O.V. Solovyev, Leningrad State University]

[Abstract] The effect of local inhomogeneities in the ionosphere on the field of a vertical magnetic dipole in the ground layer and on propagation of electromagnetic waves through the ground waveguide is analyzed by treating the ionosphere as a plane locally nonhomogeneous waveguide and representing the nonhomogeneity of its upper boundary by a nonuniformly distributed surface impedance. The problem is reduced to an integral equation and the latter is solved in the linear approximation of the perturbation theory, the surface integral being evaluated for two extreme cases. In the first case an inhomogeneity is located far from both transmitter and receiver. In the second case an inhomogeneity, a circular region, is located directly above either the transmitter or the receiver and its center lies on the extension of the dipole axis. As a specific example is considered an inhomogeneity in the ionosphere which forms as a result of heating by short-wave radio emission. The effect of such an inhomogeneity on a vertical dipole in the ground waveguide is evaluated in terms of two parameters: 1) relative difference ΔM between the moduli of Hertz vectors in the ground waveguide underneath a quiescent ionosphere and underneath a perturbed one respectively, 2) difference $\Delta\Phi$ between the arguments of regular and perturbed Hertz vectors in the

ground waveguide. The author thanks Ye.L. Tep for assisting with computer calculations. Figures 2; references 11.

UDC 621.385.69

Conditions for Self-Excitation of Gyrotron Taking into Account Space-Charge Effects

907K0087D Gorkiy IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 11, Nov 89 (manuscript received 24 Feb 88) pp 1408-1416

[Article by V.L. Bratman and A.V. Pylin, Institute of Applied Physics, USSR Academy of Sciences]

[Abstract] The starting conditions for a weakly relativistic gyrotron in which a thin helical electron beam excites a high-Q cavity and interacts there with a high-frequency electric field is analyzed theoretically on the basis of the author's earlier analysis of building up small natural oscillations of an electron beam (ZHURNAL TEKHNIЧЕСКОГО ФИЗИКИ Vol 46, No 10, 1976), in accordance with the theory of a cyclotron-resonance maser and taking into account the negative-mass effect. All electrons entering the interaction space are assumed to have the same linear and angular velocities, with a uniform distribution of their initial cyclotron phases in an axisymmetric beam with their centroids all on the same circle. A system of two self-consistent equations is formulated for such a gyrotron. The first equation describes excitation of the cavity by a bunched electron beam so that a vortical field is generated. The second equation describes the resultant motion of an electron in both its intrinsic field and that vortical one. This equation is averaged over one cyclotron period and split into two: one for the electron energy and one for the electron phase. The entire system is then linearized, the nontriviality condition for the resulting system of three linear equations yielding the dispersion equation for the gyrotron which includes space-charge effects. The solution to this equation is obtained in the form of fractional-power series, when the current parameter is sufficiently small. The boundary-value problem for the electric field, assuming no modulation of the entrance, is then solved for the starting current and its dependence on the electron flight angle. The authors thank N.F. Kovalev and M.I. Petelin for helpful discussions. Figures 3; references 16.

UDC 621.396-621.384.3

Radiation Temperature Characteristics of Mid-Atlantic Ocean Surface Based on Measurement Data

907K0054A Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 8, Aug 89 (manuscript received 25 Feb 88) pp 945-951

[Article by T.V. Aleksandrova, T.Ye. Barkan, I.T. Bubukin, and K.S. Stankevich, Scientific Research Institute of Radiophysics]

[Abstract] An experimental study concerning the radiation temperature of the sea surface was made during the 41st voyage of the scientific research vessel "Akademik Kurchatov" to the hydrophysical proving site in the mid-Atlantic Ocean. Radiation measurements were made in a vertical polarization plane at 29 different angles covering the -20° to $+45^\circ$ range, in 189 cycles over the period from 20 May 1985 to 5 July 1985, while the wind velocity and the water temperature as well as other meteorological variables were measured every three hours by the weather team. The instrumentation included a set of 0.8 cm wavelength and 1.35 cm wavelength radiometers. In lack of a stabilizing platform, the horizon was assumed to be at the angle corresponding to the strongest radiometer output signal. The data have been processed in two stages: reduction to a 10 m/s reference wind velocity followed by graphically plotting of the sea brightness temperature versus the water temperature at angle from -20° to 0° in 1° steps. A straight least-squares regression line representing the dependence of sea brightness temperature on water temperature was then drawn for each elevation angle. The results are compared with results of calculations on the basis of the theoretical equation for the sea brightness temperature. The deviation of readings at the 0.8 cm radiometer wavelength, less influenced by the atmosphere, could be attributed either to the surface ripple or to the difference between water temperature at skin-layer depth (approximately 0.5 mm) and water temperature measured by the standard method. The deviation of readings at the 1.35 cm radiometer wavelength, more influenced by the atmosphere, could be attributed to that influence as well as to the different water temperature at skin-layer depth (approximately 0.7 mm) or the surface ripple. The authors thank A.V. Khrulev for great assistance in performing the experiment. Figures 4; references 16.

UDC 538.56

Diffraction of Electromagnetic Wave by Two Homogeneous Dielectric Bodies

907K0054B Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 8, Aug 89 (manuscript received 25 Jan 88) pp 1009-1014

[Article by Ye.N. Vasilyev, V.F. Makkaveyeva, and V.V. Solodukhov, Moscow Institute of Power Engineering]

[Abstract] The problem of diffraction is solved, first analytically by the method of integral equations based on Green's identities, for a plane electromagnetic wave and two homogeneous cylinders made each of a different dielectric material, one cylinder having a circular cross-section and one having an arbitrary cross-section with a smooth contour. Assuming that the wave is E-polarized, the problem is reduced to a system of linear algebraic equations by the Krylov-Bogolyubov method and the matrix coefficients are calculated by the Simpson method of numerical integration. The results indicate a weak coupling between such dielectric bodies, each behaving like a solitary scatterer, unless one is located within the "shadow" of the other. Figures 2; references 6.

UDC 621.396.62

Adaptive Resolution of Coherent Signals during Random Motion of Source and Antenna

907K0054C Gorkiy IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOFIZIKA in Russian Vol 32, No 8, Aug 89 (manuscript received 4 Mar 88) pp 1046-1048

[Article by G.V. Serebryakov, Gorkiy State University]

[Abstract] Resolution of two coherent signals in the form of plane waves is considered upon their arrival at a receiver antenna from two directions, one directly from the source and one after reflection by some body, while the receiver antenna, a linear equidistant array of n elements, as well as the signal source and the reflector are moving in a random manner. An analysis of the problem and calculations based on the covariance matrix for the two signals, assuming Gaussian fluctuation of their phases as well as of all displacement components, yield explicit expressions for the coefficient of correlation between a direct signal and a reflected one arriving at

different angles and for the angular distribution of resultant input power. The problem and its solution have been simulated for two quasi-sinusoidal signals of the same frequency and equal amplitudes arriving at a receiver antenna consisting of four element. Figures 2; references 5.

UDC 621.391.24

Bilateral Sign Algorithm for Detection of Monochromatic Signals and Determination of Their Number

907K0055A Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 9, Sep 89 (manuscript received, after revision), 7 Sep 88) pp 3-8

[Article by L.N. Kononov]

[Abstract] A bilateral sign algorithm, a nonparametric one, is constructed for detection of monochromatic signals and determination of their number arriving at a linear equidistant antenna array. It reduces the detection and quantification problem to a sequence of s verifications that two constraints are simultaneously satisfied, which will confirm the hypothesis that the distribution of determinants $D_s(t_s)$ is symmetric with respect to zero. The algorithm, which does not involve estimating the parameters of signals at the antenna output, is demonstrated on an antenna array of M not interconnected elements receiving monochromatic signals from an unknown number N of point sources. Its effectiveness is established experimentally, by statistical simulation on a digital computer. Figures 3; references 5.

UDC 621.391.828

Algorithm for Classification of Nonhomogeneous Signal-and-Noise Sample

907K0055B Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 9, Sep 89 (manuscript received, after revision, 1 Jul 88) pp 8-12

[Article by I.G. Prokopenko]

[Abstract] An algorithm is constructed for post-detection classification of a sample of output readings which may contain a random pulse interference in addition to a mixture of a Gaussian signal and receiver noise with unknown dispersion. The probability of interference also present is assumed to be low, but its amplitude to be much larger than the r.m.s. deviation from the mean noise level. The algorithm splits a nonhomogeneous sample of readings into two parts, one a signal+noise mixture without interference and one a signal + noise mixture with interference. It is based on the general

empirical Bayes decision rule, assuming an a priori determinate vector of indicators that the sample belongs in either one of two general sets with given distributions. The algorithm is demonstrated on two specific cases, $n=r=2$ and $n=r=s=4$. Its efficiency is estimated experimentally, by the method of statistical simulation. Figures 1; references 3.

UDC 621.396.628

Comparative Evaluation of Interference Immunity of Mobile Radio Communication Systems with either Single-Sideband Modulation or Angle Modulation in Presence of both Additive and Multiplicative Interference

907K0055C Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 9, Sep 89 (manuscript received, after revision, 25 Apr 88) pp 32-36

[Article by A.A. Volkov]

[Abstract] Two mobile radio communication systems, with single-sideband modulation and with angle modulation respectively, are compared with respect to interference immunity in the presence of both additive and multiplicative interference. For this purpose, the ratio of signal power to noise power in the absence of multiplicative interference is estimated first according to the author's procedure (RADIOELEKTRONIKA Vol 29, No 9) on the basis of their spectral densities. Considering that the statistics of this ratio in the low-frequency channel are determined solely by the pattern of fast fadeouts at the receiver input, it is also estimated by the quasi-static method. Calculations for a standard telephone channel reveal a much higher interference immunity of such communication system with single-sideband amplitude modulation. References 5.

UDC 621.391.23.019.4

Space-Time Processing of Wideband Signals Mixed with Non-Gaussian Interference

907K0055D Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 9, Sep 89 (manuscript received, after revision, 9 Oct 88) pp 56-58

[Article by O.I. Shelukhin and V.N. Kravchenko]

[Abstract] Detection of a signal distributed in space and time by means of diversity receiver channels is considered in the case of a wideband signal and a non-Gaussian distribution of interference probability density in each channel. The processing algorithm is applied to a weak signal and to a noise signal with zero mean. References 4.

UDC 621.37/39:534

Modeling of Surface-Acoustic-Wave Transducers with Internal Reflectors

907K0055E Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 9, Sep 89 (manuscript received 4 Apr 88) pp 62-64

[Article by Ye.A. Nelin]

[Abstract] Modeling of surface-acoustic-wave transducers with internal reflectors is done by the method of generalized equivalent circuits rather than by the method of coupled waves, such transducers being structurally and technologically more advantageous but also requiring a more extensive analysis than plain unidirectional interdigital ones. Excitation of a wave is shifted to the center of the interdigital structure and its reflection by the electrodes is simulated with long acoustic transmission lines consisting of quarter-wavelength segments with alternately higher and lower wave impedance $R_0 - R_c \dots R_c$. This model yields readily the Y-matrix parameters and the condition for preferred directionality, namely unidirectionality, of such a transducer. Design and performance analysis is demonstrated on such a transducer with 100 internal reflectors, thin short-circuit metal films on 128° Y-cut LiNbO_3 substrates, the results indicating a high frequency selectivity and a low conversion loss. Figures 3; references 8.

UDC 621.391.8

Parallel Data Transmission Based on Walsh Functions

907K0055F Kiev IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: RADIOELEKTRONIKA in Russian Vol 32, No 9, Sep 89 (manuscript received, after revision, 6 Jun 88) pp 91-93

[Article by V.A. Vershinin]

[Abstract] Parallel data transmission for higher immunity to pulse interference is considered, use of Walsh functions being the appropriate method. It is demonstrated on realization of a signal consisting of 16 elements upon transmission of the binary code 01111110111110. The probability of reception error is calculated analytically for an additive mixture of signal and normal noise with a given spectral density, also for the practical case of peak signal power rather than signal energy limitation in the transmission line. A system with use of a 2-level group signal is proposed which, at a given peak signal power, ensures a higher immunity to noise and to pulse interference. It consists of a STROB device for preliminary processing, a low-pass input filter, a comparator, and two output AND gates in parallel. Figures 3; tables 1.

UDC 621.372.822.001.24

Solution of Scattering Problem for Conducting Cylinder in Rectangular Waveguide

907K0057A Moscow RADIOTEKHNIKA I ELEKTRONIKA in Russian Vol 34, No 8, Aug 89 (manuscript received 9 Apr 87) pp 1587-1596

[Article by M.M. Ivanishin]

[Abstract] The problem of diffraction is solved for a thin hollow metal cylinder, a tuning slug in a rectangular waveguide. The analytical solution is based on the corresponding integral equation, which takes into account not only that the height of this protrusion is adjustable but also that the density of the surface vector-current varies along its height as well as around its circumference. The solution to this equation fully identifies and describes the scattering characteristics of such an obstacle in the path of wave propagation, including resonance effects. The problem has been solved numerically, by numerical integration with the aid of cubic splines, for a variable-height cylinder projecting radially as well as for a cylinder spanning the entire width of the waveguide with a gap at the center and for an inductive cylinder spanning the entire width. The author thanks B.Z. Katsenelenbaum for discussion. Figures 4; references 13.

UDC 621.371.351

Broadening of Spectral Line of Decimetric and Centimetric Radio Waves During Radio Communication with 'Venera-15,16' Spacecrafts through Circumsolar Plasma

907K0057B Moscow RADIOTEKHNIKA I ELEKTRONIKA in Russian Vol 34, No 8, Aug 89 (manuscript received 29 Dec 87) pp 1596- 1603

[Article by A.I. Yefimov, O.I. Yakovlev, A.S. Vyshlov, A.S. Nabatov, S.N. Rubtsov, and A.D. Sheverdyayev]

[Abstract] An analysis of data on the solar corona and supercorona obtained during the May-July 1984 period from both "Venera-15" and "Venera-16" spacecrafts transmitting radio signals at decimetric (32 cm) and centimetric (5 cm) wavelength reveal a broadening of the spectral lines upon passage through the circumsolar plasma. The breadth of the 32 cm spectral line increased from its nominal 0.2 Hz, depending on the distance from the sun in solar radii, by up to 656.0 Hz at $2.5R_0$ and by less than 0.2 Hz at distances farther than $40 R_0$. The breadth of the 5 cm spectral line increased from its nominal 0.2 Hz by up to 30 Hz at $4.7R_0$ and not at all farther than $7R_0$ (any broadening at distances farther than $8R_0$ was due to distortions caused by the spacecraft). These data pertain to radio waves passing through that plasma once. The broadening of their spectral lines was up to 4 times larger upon passage through that plasma twice, for coherent reception. Another noteworthy revelation is that the ratio of signal bandwidth

upon double passage to the bandwidth to signal bandwidth upon single passage, through the circum-solar plasma, decreases as the wave propagation path skirts the sun at a closer distance. The authors thank A.I. Kucheryavenkov for assistance in processing the experimental data. Figures 4; tables 2; references 16.

UDC 621.371.332.01

Correlation Between Frequency Fluctuations of Radio Waves Propagating through Turbulent Atmosphere

907K0057C Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 8, Aug 89 (manuscript received 29 Jan 88) pp 1628- 1632

[Article by N.A. Armand and Ye.A. Lobanov]

[Abstract] The correlation between frequency fluctuations of radio signal arriving from a stationary satellite at two interferometer points in a ground station after passage through a turbulent atmosphere is evaluated, considering that a frequency fluctuation of a signal is equal to the time derivative of the time-dependent fluctuating part of the signal phase. Calculations are based on a dielectric permittivity of the atmosphere consisting of a part which anisotropically fluctuates according to the appropriately modified Karman model in addition to the regular part which varies along the wave propagation path. These calculations reveal that the correlation function for a signal received at any of the two interferometer points depends not only on the interferometer base length and orientation as well as on the satellite location but also on the variation of the refractive index characterizing a nonhomogeneous atmosphere. The correlation function decreases as the anisotropy of inhomogeneities in the atmosphere becomes stronger. The effect of anisotropy, moreover, depends on the interferometer base length and on the signal correlation time, as calculations made for a correlation time much shorter than the characteristic inhomogeneity transport time and for a correlation time longer than that indicate. Figures 3; references 3.

UDC 621.376.4

Acoustooptic Demodulation of Differential-Phase-Shift Keyed Signals

907K0057D Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 8, Aug 89 (manuscript received 11 Jan 88) pp 1756- 1759

[Article by V.S. Kulakov, Yu.I. Nikitin, Ye.Yu. Nikiforova, and L.N. Preslennov]

[Abstract] An acoustooptic demodulator with unidirectionally propagating sound beams is considered for differential-phase-shift keyed signals. It consists of a laser, two identical acoustic light modulators placed one behind the other parallel but not coaxially, and a photodetector. Its performance is analyzed, assuming that the transverse misalignment of the two modulators is equal

to the product of sound wave velocity by interaction time with one pulse. Operation of such a demodulator is shown not to be limited to one clock frequency and to be compatible with subsequent digital processing of the demodulated signal. Figures 2; references 6.

UDC 621.371.32.029.62

Conditions for Existence of Long Surface Channels for Propagation of VHF Radio Waves

907K0057E Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 8, Aug 89 (manuscript received 6 Oct 87) pp 1760- 1763

[Article by M.F. Zlotnikov and L.A. Olesov]

[Abstract] An experiment was performed during the November-December 1982 period concerning propagation of VHF radio waves over long ground channels within the Yakut ASSR with a severe continental winter climate. The measurements have yielded altitudinal temperature profiles with temperature peaks within 60-120 m altitude and temperature gradients reaching $-28^{\circ}\text{C}/\text{km}$, also refractive index gradients about twice as large as in a "normal" troposphere even though humidity is a negligible influencing factor below -20°C . The effect of significant temperature inversions on propagation of VHF radio waves in that region at that time of year was measured with a surface radar operating at metric wavelength. Blips on the radar screen representing reflections by the earth surface anomalously far from the station served as indicators of an existing long ground channel, up to 110 km long in the case of normal refraction. Calculations based the experimental data and on the theory of refraction, assuming normal refraction with a $4 \cdot 10^{-8} \text{ m}^{-1}$ gradient, strong refraction with a 10^{-7} m^{-1} gradient, or critical refraction with a $16 \cdot 10^{-8} \text{ m}^{-1}$ gradient, reveal a strong correlation between occurrence of temperature inversions and appearance of blips representing anomalously far reflections of VHF radar signals. Figures 3; references 3.

UDC 621.372.832.01

Field Plotting in Problems of Wave Diffraction at Bends of Rectangular Waveguide

907K0024A Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 9, Sep 89 (manuscript received 2 Mar 88) pp 1809-1817

[Article by V. M. Temnov]

[Abstract] A rectangular waveguide with ideally conducting walls is considered which bends sharply so that the first segment terminates into a wedge abutting the second segment. An electromagnetic wave of the H_{p0} -mode enters the first segment and bends into the second one, the first segment with vacuum inside having a finite length and the second one with a dielectric filler assumed to be semiinfinitely long. For field plotting and calculation, the entire structure is correspondingly subdivided into three partial regions. The electromagnetic field in

the regular region of the first segment is calculated in terms of infinite series, upon having been represented as a superposition of two fields: that of the incident wave and that of the reflected one (the incident wave being partially reflected by the second segment). The electromagnetic field in the wedge part of the first segment is calculated by treating this region as one beyond convergence of those series, assuming field radiation in the second waveguide segment. The problem is solved analytically for a bend in the H-plane and for a bend in the E-plane of such a waveguide. A numerical solution of both problems is shown for various angles between the two segments, the field components having been calculated by the projection method with the appropriate boundary conditions and the system of linear algebraic equations for the series coefficients having been solved by the reduction method. Figures 2; tables 2; references 12: 11 Russian, 1 Western.

UDC 621.371.342

Experimental Studies Concerning Anomalies of Optical Wave and Radio Wave Diffraction at Large Zenith Distances

907K0024B Moscow *RADIOTEKHNIKA I ELEKTRONIKA in Russian Vol 34, No 9, Sep 89* (manuscript received 30 Mar 88 pp 1817-1821)

[Article by V. I. Sergiyenko, G. I. Modestova, Yu. S. Myasnikov, L. I. Chirkova, and A. V. Shabelnikov]

[Abstract] The results of experimental studies made over the 1985-88 period concerning astronomical refraction of optical and radio waves are analyzed and evaluated, measurements in the optical range of wavelengths having been made with a Astronomical Universal 2/2 instrument. Its readings of stellar zenith distances and hour angles were corrected for human and instrument error according to the Somner-Akimov method on the basis of star passages at small zenith distances. Measurements in the radio-frequency range were made with an MKh-1507 Doppler system and a "Transit" Satellite Doppler Positioning radar, using 150 MHz and 400 MHz signals. The r.m.s. error of frequency measurements did not exceed 0.01 Hz over a period of 4.6 s. The dependence of the refraction angle on (difference between true and apparent zenith angles of a star) on the change of frequency owing to refraction has been calculated according to a formula which includes the velocity of the satellite, assuming spherical layers of the atmosphere. The data have also yielded the dependence of the refraction angle and thus of the apparent zenith angle on the time day and night as well as on the season. The following bright stars were probed with the AU 2/2 instrument during the period from October 1986 to October 1987: α Bootes, α Auriga, α Perseus, α Virgo, and stars in the Orion constellation. Figures 3; tables 3; references 8: 7 Russian, 1 Western.

UDC 551.510.535

Shift of Radio-Signal Carrier Frequency Within Region of Maximum Electron Concentration in Ionospheric Layer

907K0024D Moscow *RADIOTEKHNIKA I ELEKTRONIKA in Russian Vol 34 No 9, Sep 89* (manuscript received 30 Sep 87 pp 1845-1849)

[Article by N. I. Bushulkin, V. I. Zakharov, and S. F. Mirkotan]

[Abstract] Reflection of a radio pulse signal by an isotropic ionospheric layer is analyzed in the scalar approximation, of interest being the downward shift of the signal carrier frequency with attendant quasi-linear change of signal phase distortion upon reflection when the carrier frequency of the incident signal approaches the critical frequency of the ionospheric layer and thus falls within the resonance reflection band. Calculations for a bell-shaped signal sounding the F_2 layer, the layer treated as a filter with equivalent amplitude-frequency and phase-frequency characteristics, demonstrate that the shift of signal carrier frequency can serve as means of diagnosing the fluctuation structure in a thin ionospheric layer when the main part of the signal spectrum is wider than the resonance reflection band. Figures 3; references 4: Russian.

UDC 621.396.67.01

Efficiency of Adaptive Methods of Interference Direction Finding

907K0024E Moscow *RADIOTEKHNIKA I ELEKTRONIKA in Russian Vol 34, No 9, Sep 89* (manuscript received 27 Jan 88 pp 1850-1861)

[Article by O. P. Cheremisin]

[Abstract] Two algorithms of adaptive direction finding, the Caypon algorithm and the "thermal noise" algorithm, as well as their regularized versions are evaluated for accuracy of determining the direction of interference signal arrival from any one of the multitude of interference point sources existing in space. As reference is selected the maximum attainable accuracy of direction finding by a linear antenna array, assuming that internal interference and noise in the antenna channels are Gaussian stationary and stationarily correlated processes. An analysis of each algorithm reveals that the regularized ones are faster and that the regularized "thermal noise" algorithm, moreover, yields asymptotically efficient estimates of the angular coordinates of an interference sources. References 6: 4 Russian, 2 Western.

UDC 621.391.01

Processing of Radar Data in Measuring Systems from Standpoint of Group Theory907K0024F Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 9, Sep 89
(manuscript received 28 Sep 87 pp 1878-1885)

[Article by Yu. G. Bulychev and A. A. Korotun]

[Abstract] Processing of radar measurement data from by application of group theory is outlined, such a method ensuring full utilization of a priori data on target movement for estimation of constant systematic errors and computer-efficient compensation of slowly varying systematic errors as well as of constant ones. The problem of target locating is solved first in the dynamic formulation on the basis of the mathematical model $dX/dt = f(t, X, V)$ (X - transposed vector of target coordinates, V - transposed vector of arbitrary functions of time t , f - transposed vector of functions differentiable with respect to t, X, V) with X_0 and V_0 denoting X and V at time $t = 0$. The problem is then solved in the kinematic formulation, with the target phase trajectory stipulated as a sequence of segments representing each the action of some group law $T_{\text{vector } A}$ on point X in space R^N so that $T_{\text{vector } A} : \text{vector } X = \text{vector } H(\text{vector } X_0, \text{vector } A, \text{vector } \Xi)$ (H - transposed vector of continuously differentiable and locally invertible functions) with $X = X_0$ when vector $A = \text{vector } A$ at time $t = 0$. An analysis of the probability characteristics of such a target locating is followed by two examples: 1) target motion in a circular orbit around Earth estimated on the basis of a system of three differential equations, one for each of the three Cartesian coordinates; 2) target trajectory estimated on the basis of a system of three expansion group equations with a single parameter. References 15: 14 Russian, 1 Western (in Russian translation).

UDC 681.7.069.32

Determination of Effective Frame Duration in Image Converter Tubes with Grid Shutter907K0024G Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 9, Sep 89
(manuscript received 17 Jun 89 pp 1945-1951)

[Article by V. P. Degtyareva, V. V. Ludikov, V. A. Podvyaznikov and V. K. Chevokin]

[Abstract] An electronic high-speed camera for study of fast processes has been developed on the basis of the PIM-105V image converter tube with an S-20 photocathode and a grid shutter. Four frames are formed in it by application of four electrical shutter pulses across the interelectrode gap in synchronism with square-wave pulses applied to one of the deflection plates. The design of this "Sapfir-Kadr" camera draws upon the results of dynamic tests, the square-wave voltage having been replaced with a sawtooth voltage for measurement of the photoelectron pulse duration. The time characteristics of the shutter have been analyzed on the basis of the simplest model, namely

a uniform electric field between two plane electrodes placed at a given distance apart. The data indicate the feasibility of decreasing the exposure time to 0.38 ns by application of a 70 V bias and 120 V shutter pulses, the photoelectron utilization factor then being only 50%. A higher utilization factor and a speed of 2×10^9 frames/s maximum are attainable by application of a 500 V bias and 1500 V shutter pulses with a flat top of 300 ps duration after a 200 ps rise time, the photocathode-grid channel having a 1.5 GHz bandwidth allowing for such a short rise time. Figures 4; tables 1; references 6: 4 Russian, 2 Western.

UDC 621.371.342

Attenuation of Centimetric Ground Waves Owing to Interference907K0024H Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 9, Sep 89
(manuscript received 20 May 88 pp 1967-1970)

[Article by V. N. Pozhidayev and A. V. Shabelnikov]

[Abstract] Experimental data pertaining to propagation of centimetric ground waves and indicating attenuation of the latter are interpreted theoretically on the basis of a three-rays interference pattern at the receiver site. The experiment was performed with 11.5 GHz, 19.2 GHz, and 29.2 GHz radio waves in summer 1987 during dry-weather nights in the central region of the European part of the USSR, the transmitter antenna stretching 30 m above ground covered with a conifer forest and measurements being made over 2-3 h periods at a distance of 12.65 km with a receiver antenna 1 m in diameter. The field at the receiver point is calculated disregarding both sphericity of the earth and refraction but including phase advances due to the altitude-dependent and thus nonuniform reflection coefficient of air, this field being the resultant one of the signal which has arrived directly and the two signals which have arrived after reflection by the ground surface or by the inversion layer respectively. The calculations confirm the possibility of three-rays interference being the cause of attenuation, the signal reflected by the ground surface preventing fadeout. The magnitude of such an attenuation depends on several factors, including the altitude and the reflection coefficient of the inversion layer. Figures 2; references 5: 3 Russian, 2 Western (1 in Russian translation).

UDC 621.396.96.01

Algorithms for Compensation of Ionospheric Error in Radio Altimeters907K0024I Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 9, Sep 89
(manuscript received 21 Dec 87 pp 1983-1986)

[Article by V. M. Pavlov and Yu. S. Rascheplyayev]

[Abstract] The algorithm for compensation of the regular ionospheric error in radio altimeters, which involves calculation of the signal delay time by expansion into a

series $t_N = t_0 + \sum_{k=1}^N a_k \omega_0^k dt_0(\omega_0/d\omega^N$ from $k=1$ to $k=N$ (t_0 -group delay time at frequency ω_0 , a_k - real coefficients, N -number of ionospheric error components), is modified by replacement of the derivatives with central differences for calculation of the time delay due to each error component separately. An estimate of the methodological error incurred by this approximation, based on calculation of the time delays due to the first and second error components only, indicates that such a modification leads to a more accurate compensation. Figures 1; references 4: 3 Russian, 1 Western (in Russian translation).

UDC 551.510.522

Measurements of Size Distributions of Raindrops and Estimation of Attenuation Coefficients for Radio Waves

907K0075A Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 10, Oct 89 (manuscript received 20 Jun 88) 2017-2022

[Article by M.V. Zakharyan, L.N. Kornilov, and V.N. Pozhidayev]

[Abstract] The diameters of raindrops in precipitations over the Dubna area were measured with a photoelectric transducer over the May-September 1987 period. The data have been processed for evaluation by two different methods. In accordance with the first method, the spectra obtained at rain intensities within bands ranging from -10% to +10% of nominal intensity R were averaged and then approximated with the best fitting distributions by matching the parameters of the latter. The log normal distribution was found to fit better than the Marshall-Palmer distribution, especially in both small- size and large-size ranges of the spectra. In accordance with the second method, without use of model distributions, both the rain intensity R and the attenuation coefficient γ for radio waves of a certain frequency were calculated for each recorded distribution, whereupon the constants k and α in the relation $\gamma = kR^\alpha$ were calculated by the regression method using a data array of 1254 points and covering the 15-70 GHz frequency range. The results are compared with predictions made according to the CCIR method, which had overestimated the attenuation coefficient. Figures 5; tables 1; references 8.

UDC 621.371.342

Resolving Power Of Antennas in Anisotropic Medium

907K0075B Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 10, Oct 89 (manuscript received 19 Jan 88) pp 2029-2031

[Article by Ye.A. Lobanov and A.N. Lomakin]

[Abstract] The resolving power is calculated for two linear antennas, a vertical and a horizontal one, each based on ground and receiving signals from two sources

through turbulent air. The two sources are assumed to have the same power and to be located symmetrically with respect to the antenna. The effect of large-scale atmospheric turbulence is manifested in the fluctuation spectrum of the air's refractive index and in resulting signal phase fluctuations at the antenna. First is considered the generalized anisotropic model and then Lomakin's anisotropic modification of the Karman model as a specific example. In the case of a strongly anisotropic turbulence, a vertical antenna is found to resolve the sources better at large zenith angles, as indicated by a sharper contrast in the readings. Figures 1; references 5.

UDC 533.9.082.74

Reflection of Electromagnetic Pulse by Parabolic Layer of Anisotropic Absorbing Plasma

907K0075C Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 10, Oct 89 (manuscript received 2 Feb 88) pp 2032-2038

[Article by V.K. Berger]

[Abstract] Reflection by a radiation-absorbing parabolic plasma layer of a square electromagnetic pulse carrying a high-frequency packet and propagating along a constant magnetic field which makes the plasma anisotropic is analyzed, this pulse being an either ordinary or extraordinary one. The electric field of the reflected pulse in the time domain, equal to the integral from minus to plus infinity of the reflection coefficient in the frequency domain, is calculated with the aid of the incomplete gamma function and its asymptotic expansion. Calculations are made for a circularly polarized and linearly polarized incident pulses. An analogous procedure can be used for determining the form a pulse transmitted by such a plasma layer. Figures 3; references 4.

UDC 621.396.67.01

Radiation Pattern of Array of Convergent Wave Beams

907K0075D Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 10, Oct 89 (manuscript received 22 Feb 88) pp 2038-2045

[Article by N.P. Maryin]

[Abstract] The radiation pattern of an array of parallel of identical convergent Gaussian beams carrying coherent fundamental-mode electromagnetic waves is calculated, first in the Fresnel region and then in the Fraunhofer region, assuming that the distances between them are comparable with the wavelength. The field distribution and its phasing dynamics in the space from where the radiation pattern evolves are evaluated on the basis of the Fresnel approximation. The results indicate that a linear array of such wave beams can be regarded as an array of secondary elementary radiators and, in effect, constitutes a spatially phased antenna. Figures 4; references 3.

UDC 621.396.96.01

Maximum-Likelihood Estimates of Form and Bearings of Linearly Independent Signals

907K0075E Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 10, Oct 89 (manuscript received 14 Dec 87) pp 2094-2102

[Article by A.M. Vagapov]

[Abstract] Algorithms based on the maximum-likelihood criterion are constructed for finding the direction and estimating the form of M linearly independent signals detected by a multichannel antenna having at least $M + 1$ channels with independent but identically distributed noise in each. Considering that the bearing matrix of a sequence of monotonically increasing angles read non-coincidentally is a matrix of full rank, it ensures uniqueness of the solution to equivalent direction finder equations for an active antenna sector projected on a linear shell by means of the MUSIC algorithm. This solution yields the vector of geometric properties and thus the form of the channel signals. The logarithm of the maximum-likelihood ratio is obtained on the basis of measurements over a sufficiently long period of time with sufficiently wideband amplifiers in the antenna channels. Bearing estimates are then obtained following formation of the null-bearing characteristic and estimation of its minima (zeroes). References 20.

UDC 621.396.67.01

Synthesis of Frequency Characteristics of Spin Wave Devices Based on Antenna Arrays with Curvilinear Profile

907K0075F Moscow *RADIOTEKHNIKA I ELEKTRONIKA* in Russian Vol 34, No 10, Oct 89 (manuscript received 9 Jan 89) pp 2233-2236

[Article by V.F. Dmitriyev]

[Abstract] The design of a spin wave filter is analyzed, its frequency characteristics being synthesized by appropriate selection of the microstrip antenna array in which an as closely as possible to the necessary space distribution of surface current is attainable by apodization and "weighting" of its elements. A microwave antenna array is considered whose current-carrying electrodes have curvilinear profiles and are located near the surface of a ferromagnetic film at successively larger distances the latter. The frequency dependence of its radiation resistance is determined for solution of the filter synthesis problem by matching the required amplitude-frequency characteristic. The procedure is applied, for illustration, to a spin wave filter with a square amplitude-frequency characteristic. The equation for the electrode profile function has been solved numerically on a computer. Figures 3; references 3.

UDC 621.396.967:629.735.33

Spatial Characteristics of Radar with Synthesized Aperture under Severe Limitation of Input Signals

907K0050A Moscow *RADIOTEKHNIKA* in Russian No 9, Sep 89 (manuscript received, after completion, 13 Dec 88) pp 4-6

[Article by K.G. Papushin and N.I. Neilo]

[Abstract] Severe limitation of input signals to a radar receiver with a synthesized aperture is considered and the effect of the resulting non-linearity on such an aperture is evaluated by harmonic analysis of a mathematical model using the frame scan algorithm. The results of computer calculations indicate that severe limitation of resolvable signals does not significantly widen the major lobe of a synthesized radiation pattern but widens its side lobes. Figures 2; references 5.

UDC 621.396.253

Derivative Signal Systems and Their Characteristics

907K0050B Moscow *RADIOTEKHNIKA* in Russian No 9, Sep 89 pp 16-17

[Annotation of article by I.D. Gorbenko and Yu.V. Stasev, deposited at the Central Scientific and Technical Institute 'Informsvyaz' under No 1446-sv]

[Abstract] Derivative orthogonal signal systems with $L = 2^r$ elements ($r = 1, 2, 3, 4, \dots$) for any L identically equal to 0 (mod 4) are analyzed for their effectiveness in lowering the probability error in communication systems. Their correlation, ensemble, and structural characteristics are found to be excellent, depending of the characteristics of the generating signal system. The latter should be optimal with respect to periodic autocorrelation and cross-correlation functions in terms of lateral excursions. The statistical characteristics of autocorrelation and cross-correlation functions for derivative signal systems as well as for those of complete code rings, nonlinear derivative code sequences, and Gold sequences have been estimated. The mean values of these estimates are shown. Tables 2.

UDC 621.396.62

Energy Losses in Digital Receivers of Pseudonoise Signals

907K0035C Moscow *RADIOTEKHNIKA* in Russian No 9, Sep 89 pp 57-58

[Article by A.N. Bondarev, M.I. Zhadzhishskiy, and S.Yu. Sila-Novitskiy, deposited at the Central Scientific and Technical Institute 'Informsvyaz' under No 1461-sv]

[Abstract] Decoding of a signal continuously phase-shift keyed by a flux of binary information carrying symbols is considered and the usually high energy losses, in a receiver of such pseudonoise signals are analyzed for the

case of independent readings. Such a receiver first locks the convolution of an incoming pseudonoise signal with the local reference pseudonoise signal, then tracks the signal delay and locks the signal carrier, finally demodulates the informative symbols. The analysis of energy losses during both signal delay tracking and signal carrier locking is based on quasi-continuous models of these two processes. The results of calculations indicate the advisability of using a two-level reference pseudonoise signal in a receiver with analog convolution of incoming pseudonoise signals and a three-level one in a receiver with digital-analog or digital-digital convolution. The energy losses are even higher in asynchronous digital-analog and digital-digital receivers. References 4.

UDC 621.396:62.019.4

Interference Compensation during Detection of Signal with Random Amplitude and Initial Phase

907K0050D Moscow *RADIOTEKHNIKA in Russian*
No 9, Sep 89 pp 59-61

[Annotation of article by V.P. Tuzlukov, deposited at the Central Scientific and Technical Institute 'Informsvyaz' under No 1435-sv]

[Abstract] The feasibility of interference compensation during detection of a signal by the correlation method is considered in the case of a signal with random amplitude and initial phase, assuming that the model of such a signal and the interference interact at the receiver site. Combining the correlation method with the autocorrelation method is shown to yield the desired compensation effect, inasmuch as a stiff functional relation exists between interference components in the two channels of a receiver-filter synthesized for autocorrelational-correlational processing.

UDC 621.396.677.83

Dielectric Structures Supporting Reflector Antennas

907K0050E Moscow *RADIOTEKHNIKA in Russian*
No 9, Sep 89 (manuscript received 3 Nov 88) pp 63-68

[Article by T.L. Gruzinskaya, G.G. Tsurikov, and V.G. Yampolskiy]

[Abstract] Considering that a dielectric supporting structure lowers the efficiency of a reflector antenna and raises the level of fringe radiation, this shadowing effect of a dielectric support is compared with that of a metal one. The analysis is in each case based on the classical problem of diffraction and forward scattering of plane electromagnetic waves with E or H polarization by an infinitely long circular cylinder supporting an axisymmetric antenna. Power calculations made accordingly indicate that a dielectric support made of a material specially matched with respect to permittivity will influence the electrical performance characteristic of an antenna even less than a metal support, especially when

such a "bleached" support is thin with a diameter of the order of a half-wavelength. Figures 14; references 5.

UDC 621.396.021.12

Use of Digital Filtration for Decreasing Random Errors of Antenna Measuring Apparatus

907K0050F Moscow *RADIOTEKHNIKA in Russian*
No 9, Sep 89 (manuscript received, after completion, 29 Nov 88) pp 71-74

[Article by R.I. Rumyantsev]

[Abstract] Decreasing random errors in measurement of antenna performance characteristics by means of digital filtration is considered, measurement of the field amplitude-phase distribution in the antenna aperture either leading to reconstruction of the antenna radiation pattern and yielding the space spectrum of a random field. The object is to obtain both with the minimum possible error on the basis of a single realization. The results of theoretical analysis and simulation on a YeS-1033 computer indicate that digital filters in the form of smoothing windows do, indeed, decrease random error in the case of a uniform amplitude-phase distribution. In the case of a nonuniform one, however, matching the window characteristics is a difficult problem. Figures 2; references 7.

Semiconductor Memories Suitable for Microprocessor Systems

907K0050H Moscow *RADIOTEKHNIKA in Russian*
No 9, Sep 89 pp 94-95

[Article by M.I. Maslov and V.V. Pavlov]

[Abstract] Following a classification of semiconductor memories according to functional criteria in *RADIOTEKHNIKA* No 8 (August 89), they are now classified according to technological and application criteria into two groups: bipolar and MOS-devices. Memories of the first group are used in ESL, TTL, SDTTL, and I²L circuits. In the second group belong p-MOS, n-MOS, and CMOS memories. Random-access memories are designed to be either static with potential triggers and a single power supply or dynamic with data stored in the form electric charge on a MOS-capacitor. These are prevalently used in microcomputers as well as in peripheral equipment and buffer storages. Listed are the basic design and performance parameters of 8 static and 37 dynamic random-access memories built on integrated-circuit chips of various standard series. Tables 2; references 4.

UDC 621.396.66

Automatic Phasing of Multichannel Output to Common Reference Signal*907K0064A Moscow RADIOTEKHNIKA in Russian No 10, Oct 89 (manuscript received, after completion, 20 Jan 89) pp 12-14*

[Article by A.P. Pirkhavka]

[Abstract] Two schemes are proposed for automatic phasing an N-channel radio transmitter output stage to a common reference signal which will ensure high stability of the phase distribution and will not depend on the spectrum of the input signal. Automatic phasing to the output signal of a reference channel requires a system which includes N-1 closed phase loops. Automatic phasing to the signal of an external stable-phase oscillator with attendant compensation the phase unbalance will stabilize the average phase of the N channels but may also suppress the useful angle modulation of the phased signals and prevention of this possibility must be built into the system. Figures 2; references 4.

UDC 621.396.62

Integrated-Circuit Version of Intermediate-Frequency FM Amplifier*907K0064B Moscow RADIOTEKHNIKA in Russian No 10, Oct 89 (manuscript received, after completion, 11 Dec 88) pp 34-36*

[Article by A.V. Krivosheykin and M.G. Moshkovich]

[Abstract] The design of an intermediate-frequency FM amplifier economically producible in the semiconductor integrated-circuit version is analyzed, this 10.7 MHz amplifier consisting of six or more symmetric differential stages connected into a cascade without decoupling capacitors. Each stage contains 12 transistors and draws a current of 0.22-0.25 mA. Each has a feedback loop to one of its inputs, the one drawing current through a transistor stage which stabilizes it for the 2-9 V range of supply voltage. Current transfer to the feedback loop is effected by a transistor pair which forms a "current mirror". The performance of this amplifier was evaluated experimentally, on a prototype differential stage with n-p-n transistors, and found to satisfy all requirements. Figures 2; references 3.

UDC 621.382.8

Model of Charge-Coupled Devices with Stepped Dielectric Layer*907K0064C Moscow RADIOTEKHNIKA in Russian No 10, Oct 89 (manuscript received, after completion, 5 Jan 89) pp 36-38*

[Article by V.Ye. Prozorovskiy]

[Abstract] A mathematical model of a charge-coupled device with stepped dielectric layer insulating the two transfer electrodes from the substrate is constructed on the basis of a one-dimensional physical model. A partial differential equation describes the rate of change of charge as a function of the space coordinate along which a step change of the layer thickness occurs so that the layer remains thicker under one electrode than under the other. The steady-state performance and the transient characteristics of such a device are analyzed on the basis of an electric circuit which simulates it in accordance with this model. Figures 5; references 6.

UDC 621.396.96

Models of Electromagnetic Pulses from Lightning and from Electrostatic Discharge*907K0064D Moscow RADIOTEKHNIKA in Russian No 10, Oct 89 (manuscript received 28 Nov 88) pp 48-49*

[Article by K.V. Tuzov]

[Abstract] The waveform of lightning current and of electric-discharge current is described analytically, as a basis for calculating the parameters (amplitude, rise time) of electromagnetic pulses generated by lightning or electrostatic discharge. Consideration of a solitary pulse is adequate, inasmuch as recurring pulses are separated by intervals usually longer than their durations. The results of calculations and measurements are evaluated with reference to the applicable GOVERNMENT STANDARD 1516.2-76 dealing with design of radioelectronic apparatus for electromagnetic compatibility and interference immunity. Figures 2; references 4.

UDC 621.391.2.519.25

Unbiased Digital Detector of Signals Mixed with Interference*907K0064E Moscow RADIOTEKHNIKA in Russian No 10, Oct 89 (manuscript received, after completion, 29 Feb 89) pp 55-56*

[Article by L.N. Anisimova and A.P. Koldanov]

[Abstract] Detection of a harmonic signal with unknown amplitude and random initial phase in the presence of additively mixed stationary Gaussian noise and random pulse interference is treated as a parametric problem. A binary decision rule is proposed and a detection algorithm is constructed so that the false-alarm probability depends neither on the unknown noise intensity and interference pulse intensity nor on the unknown probability of an interference pulse appearing at a given instant of time. The detection threshold is determined from a set of three equalities, most expediently by the direct sorting method. No other detection scheme was found to solve this particular detection problem. References 5.

UDC 621.396.677.71

Excitation of Elliptical Cylinder by Slot Antennas

907K0064F Moscow *RADIOTEKHNIKA* in Russian
No 10, Oct 89 (manuscript received 4 Dec 88) pp 61-65

[Article by V.A. Kravtsov, G.V. Kravtsova, and O.A. Ulasik]

[Abstract] Excitation of a hollow elliptical metal cylinder through transverse and longitudinal slots on one side is formulated as an external boundary-value problem. The field components are calculated by the Stratton method first for a transverse slot and then for a longitudinal one. The complex mutual admittance is calculated by the method of induced m.m.f.'s, both its resistive and reactive components depending not only on the ellipticity of the cylinder but also on the relative position and the mutual orientation of such slots. An analytical solution is obtained in asymptotic representations of Mathieu functions and followed by a numerical solution for half-wavelength slots on a cylinder with fixed major semiaxis and variable minor semiaxis. The results apply to slot antennas mounted on quasi-cylindrical conductor structures. Figures 5; references 5.

UDC 621.396.96

Effect of Beam Deviation from Geometrical Axis of Phased Antenna Array on Polarization Pattern of Transmitted and Received Signals

907K0064G Moscow *RADIOTEKHNIKA* in Russian
No 10, Oct 89 (manuscript received, after completion, 2 Dec 88) pp 71-75

[Article by Ye.L. Kazako and Yu.A. Kavin]

[Abstract] A problem in measuring the polarization parameters of a target with a phased radar antenna array is considered, namely distortion of the polarization pattern of both transmitted and received signals by deviation of the antenna beam aimed at the target from the geometrical axis of the antenna array. A plane array of quadrupoles is, for the purpose of analysis, treated as an orthogonal one combining two subarrays of dipoles. The polarization pattern (linear, elliptical, circular) is then determined by the amplitudes and the phases of voltages feeding the two subarrays. The measurement error due to deviation of the antenna beam is estimated by calculation of the electric field which both subarrays excite in the far zone and then the trace of the polarized-scattering matrix. This error can be eliminated by use of an adaptive scanning antenna with controllable spatial polarization characteristic. Figures 4; references 4.

UDC 621.374.387

Method of Extracting Pulse Signal

907K0064H Moscow *RADIOTEKHNIKA* in Russian
No 10, Oct 89 (manuscript received, after completion, 19 Dec 88) pp 107-110

[Article by I.F. Gavrilenko]

[Abstract] Use of the pulse repetition rate as basis for extraction of a pulse from a pulse sequence by a selector with minimum phase shift is proposed, which involves a special procedure for formation of strobe pulses. A pulse sequence coming from a high-stability quartz oscillator is divided and another pulse sequence is formed by a frequency divider, whereupon logic cross-multiplications in two AND gates generates two auxiliary pulse sequences which control an RS-trigger. The latter generates a sequence of lowest-order strobe pulses having a duration only twice as long as that of pulses in the incoming sequence. This eliminates the disadvantages of timing the incoming pulse sequence relative to a reference pulse sequence, the phase stability of a selected pulse being minimized and determined only by the switch-on time of an AND gate. The principle can be applied to formation of pulse series from an incoming sequence, formation of high-precision time delays, and pulse selection for transmission of discrete messages. Figures 5; references 12.

UDC 621.391:621.396:519.24

Some Results of Studies Pertaining to Long-Distance Tropospheric Radio Communication over Routes in Central European USSR

907K0086A Moscow *RADIOTEKHNIKA* in Russian
No 11, Nov 89 (manuscript received, after completion, 15 Feb 89) pp 14-16

[Article by Ye.Ya. Marchenko, S.V. Fedorov, and V.V. Isakevich]

[Abstract] Tropospheric radio communication at 500-600 MHz frequencies over 157-440 km single-span routes in the central region of the European USSR was tested over 72 h periods mainly in spring (March-April) and autumn (October-November) but also in summer (June) and winter (December). Signal power was measured almost around the clock, except for breaks during the day within the 2 PM - 4 PM period and during the night within the 11 PM - 5 AM period. The data were evaluated for an analysis of fast fadeouts, histograms revealing a bimodal distribution. Autocorrelation analysis has revealed oscillations of the autocorrelation function for the signal envelope in a channel with temporal dispersion, which can serve as measure of departure from Rayleigh fadeouts. This is confirmed by comparative theoretical calculations on the basis of the Middleton model, assuming that reradiators form a Poisson

flux in both space and time domains. Figures 4; references 7. and time) of reradiators.

UDC 621.396.24

Radio Echo with More than Second Long Delays

907K0086B Moscow *RADIOTEKHNIKA* in Russian No 11, Nov 89 (manuscript received, after completion, 20 Apr 89) pp 46-49

[Article by A.G. Shlionskiy]

[Abstract] Radio echo signals have been recorded arriving after seconds or tens of seconds, their delays thus being up to two orders of magnitude longer than those of signals circling the earth. No theory is available about possible mechanisms of their generation and propagation, but hypotheses have been proposed and tested which fall into two groups. The first group comprises four hypotheses referring to reflection of these signals far in outer space above the atmosphere and lower regions of the magnetosphere, namely by the moon, by large meteorites orbiting behind the moon, by ionized high-density nebulae within the Lagrange-Trojan belt of asteroids, or by charged solar particles (Stoermer hypothesis proposed in 1928 on the basis of an earlier one dating back to 1904) respectively. The second group comprises 11 hypotheses referring to generation and reflection within the ionosphere or lower regions of the magnetosphere. They include the van der Pol hypothesis, the Pedersen hypothesis of curvilinear channeling along ionized formations above the earth and rotating with it, the Villard-Muldrew hypothesis of magnetic ducts, "bubbles" of very low electron concentration stretched along the magnetic field, transformation of radio waves into longitudinal plasma waves and of the latter back into radio waves (Shlionskiy-Yashin hypothesis), ionospheric resonators formed by cavities in F-region layers or elsewhere above the earth (Shlionskiy-Ventsman hypothesis), resonant partial energy transfer from an electron beam generated principally by solar activity to the reflecting medium as a result of plasma-beam interaction, plasma memory, nonlinear wave-particle interaction involving signals at two frequencies with a difference close to the plasma frequency of the reflecting medium followed by nonlinear interaction of the difference-frequency electrostatic wave with a strong f_1 -signal generating a f_2 -signal, soliton-like nature of delayed echo signals (Shlionskiy hypothesis), and multiple circling of the earth with focusing at antipodes (Elton hypothesis). New evidence indicates several additional factors which lower the losses, namely: plasma-beam effects in discrete channel sections, combination of strong longitudinal focusing in ionospheric waveguides near maximum of vertical gradient and transverse focusing within the circumterminator zone, and possibility of quasi-periodic long-period field intensity amplification in multimode waveguides. The author thanks V. Bubnov, A. Goncharov, V. Kanevskiy, G. Rumyantsev, A. Starovoytov, A. Khasyanov, and G. Khonin for participating in observation of delayed echo signals. References 13.

UDC 621.396.692

Calculation of Atmospheric Errors in Phased Radio Systems

907K0086C Moscow *RADIOTEKHNIKA* in Russian No 11, Nov 89 (manuscript received 2 Aug 88, after completion 15 Dec 88) pp 68-72

[Article by Ye.F. Korolev]

[Abstract] For use of radio systems for high-precision measurements of the phase difference between signal transmitted or received by diversity antennas, random atmospheric errors entering into these measurements are evaluated for an interferometric phase measuring system with two apertures separated by a distance equal to the base length. The dispersion of phase errors is calculated on the basis of the autocorrelation function according to the Kolmogorov model for locally-homogeneous turbulent atmosphere as well as on the basis of structural and correlation functions describing phase fluctuations in space and time. The results of these theoretical error estimates have been confirmed by measurements with a USSR Academy of Sciences radiometer on top of the 269 m tall Ostankin Observatory tower, its base being made 175 m long and then 287 m long with both apertures in each case up to 37 km away from the radiator. The phase error squared was, indeed, found to be proportional to the propagation time or distance cubed and inversely proportional to the cube root of the base length, as long as the propagation time or distance remains shorter than then the respectively the correlation time or length for atmospheric phase fluctuations. Generally the phase error will increase nonlinearly with increasing propagation time or distance and will decrease nonlinearly with increasing radiometer base length. Figures 3; references 12.

UDC 621.372.837

Design of Wideband Microwave Switch

907K0086D Moscow *RADIOTEKHNIKA* in Russian No 11, Nov 89 (manuscript received, after completion 16 Feb 89) pp 73-75

[Article by V.P. Petrenko]

[Abstract] A wideband microwave switch with three identical quarter-wavelength strip line segments connected into a ring is described, one of the three junction nodes being connected an input line and each of the other two being connected to an output strip line. A switching diode taps into each of the two output strip line so that the two diodes intercept equal strip line segments. A performance analysis based on the scattering matrix of such a symmetric four-pole network yields the amplitude-frequency characteristic of this device and the frequency dependence of the voltage standing-wave ratio in it. Finite diode resistances in the conducting state ($r = 1 \text{ ohm}$) and in the blocking state ($R =$

3000 ohms) have almost no effect on the voltage standing-wave ratio, but the magnitude of the insertion loss is influenced by the finite diode resistance in the conducting state. The switch is smaller in size than one with additional quarter-wavelength loops. It is covered by USSR Patent Disclosure No 4,329,989/24-09 (5 October 1987). Patent was granted on 25 May 1988. Figures 2; references 3.

UDC 621.396.677.494

Dimensioning of Modules for Antenna Array with Hexagonal Aperture

907K0086E Moscow *RADIOTEKHNIKA in Russian*
No 11, Nov 89 (manuscript received, after completion,
5 Feb 89) pp 75-77

[Article by Ye.N. Korostyshevskiy and G.A. Polukhin]

[Abstract] An antenna aperture in the form of a regular hexagon is considered, such an aperture to be synthesized by an array of identical rectangular modules so that maximum packing density and thus maximum area utilization will be attained with the minimum number of modules. The problem of selecting the optimum module dimensions is solved analytically, with the area utilization factor treated as a function of the ratio of module sides and its maximum sought under given structural constraints. Two schemes are found to yield a desired solution. The modules filling the two corners on opposite sides of the rectangular center part of the hexagon are aligned in the first scheme and are shifted in the second scheme, the ratio of module (rectangle) sides being $a/b = 3^{1/2}$ and $a/b = 2(3^{1/2})$ respectively. General formulas are derived for the antenna radiation pattern in each case, with the number of modules M along one hexagon side (equal to radius R of circumscribed circle) and the number of corner steps along with the ratio R/γ (γ -radiation wavelength) as parameters. Numerical performance calculations are made for typical such antenna arrays. Figures 3; references 3.

Space Spectrum Analysis of Laser Scanner System Forming Remote Image

907K0086F Moscow *RADIOTEKHNIKA in Russian*
No 11, Nov 89 (manuscript received 7 Dec 88) pp 82-85

[Article by V.G. Shinkarenko and A.D. Karavayev]

[Abstract] Formation of a remote image of a diffusely scattering surface by a laser scanner system is analyzed, without constraints on the scan angle but assuming a laser with a Gaussian radiation pattern and a surface with a sinusoidal relief. First is considered a cylindrically sinusoidal isophotic surface and sinusoidal modulation of the laser radiation intensity, the resulting phase modulation of the photodetector signal not being sinusoidal but broadening its space spectrum. The stereospatial contrast-frequency characteristic of this signal is calculated in the linear approximation for linear phase detection, the video signal then having an amplitude proportional to its phase. The signal from a remote image is shown to be formed in this case by linear filtration but in the general case generally by spatially nonuniform filtration of the surface relief. Figures 1; references 8.

UDC 621.37/39

First Soviet Studies of Antenna System Adaptation to Interference

907K0086G Moscow *RADIOTEKHNIKA in Russian*
No 11, Nov 89 (manuscript received 4 Apr 89)
pp 108-110

[Article by Ya.D. Shirman, S.I. Krasnogorov, Ye.P. Lebedev, and G.A. Kostin]

[Abstract] Antenna system adaptation to interference was first studied in the USSR during the 1959-64 period, independently of later research done abroad during the 1965-67 period. These studies included statistical analysis of space-time resolution and detection covering both Rayleigh-Woodward resolution without interference suppression and hyper-Rayleigh resolution with interference suppression. Subsequent studies resulted in development of various interference compensation methods, namely multichannel correlational autocompensation, single-channel and 2-channel quadrature autocompensation, adaptation of antenna polarization characteristics by means of a single compensation channel, and finally polarization-directional adaptation of receiver antennas, adaptation of high-speed moving target indicators, and adaptation of directional characteristics of receiver antennas during continuous signal transmission. Figures 4; references 16.

UDC 621.3.049.75

Algorithm of Search for Potentially Unreliable Spots in Conductor Network on Printed-Circuit Board

907K0053A Kiev ELEKTRONNOYE
 MODELIROVANIYE in Russian Vol 11, No 5,
 Sep-Oct 89 (manuscript received 18 Jan 88) pp 58-62

[Article by Ye.I. Mazur, graduate student, Moscow Institute of Radioelectronics and Automation]

[Abstract] An algorithm has been devised for search of defects in the conductor network laid out on a printed-circuit board, specifically "jagged edges" defects as potentially unreliable spots. These defects are classified into significant ones which make the conductor width smaller than the minimum permissible and critical ones which make the clearance between conductors and thus the width of the dielectric separating them smaller than the minimum permissible. A defective conductor is accordingly defined as one whose width, over its entire length, alternately first exceeds and then becomes smaller than a given minimum permissible. Unevenness of the conductor edges can thus be disregarded. The algorithm is based on the method of templetless inspection, its gist being estimation of the linear dimensions of successive conductor and dielectric segments. Deviation of their linear dimensions beyond the tolerance limits is thus the sole indicator of a defective spot. The search for potentially unreliable spots is executed on the basis of input data, first about two raster lines and then about one only. The algorithm can operate in two modes with respect to parallelization of levels and storage of data. In the first mode conductors and spacers are inspected together for potentially unreliable spots successively in three directions: horizontal, vertical, and diagonal. Some constraints are imposed here on positioning of the printed-circuit board. The second mode involves parallel inspection of conductors and spacers in all three directions simultaneously, there being no constraints imposed on positioning of the board. The algorithm is suitable for intricate as well as simple printed-circuit configuration. Its execution in real time requires a speed higher than that of available microcomputers. A simulator for checking it has, however, been developed for which an Iskra-226 microcomputer is adequate. Figures 2; tables 1; references 4.

UDC 681.326.7

Analysis and Optimal Design of Self-Diagnosing Systems

907K0090A Kiev ELEKTRONNOYE
 MODELIROVANIYE in Russian Vol 11 No 6,
 Nov-Dec 89 (Manuscript received 8 Feb 88; after
 revision 27 Oct 88), pp 34-38

[Article by B. S. Stogniy, Corresponding Member, Ukrainian Academy of Sciences, A. V. Kirilenko, Candidate of

Technical Sciences, E. S. Kokhno, Junior Scientific Fellow, Institute of Electrodynamics, Ukrainian Academy of Sciences, Kiev]

[Abstract] The design stages of self-diagnosing systems are discussed. A method is developed, criteria and algorithms are suggested for probability mutual monitoring models. The basic results are presented from determination of the set of permissible defects in fully connected and nonfully connected systems by an analytic method. The result is a simple and effective procedure for optimal synthesis, significantly expanding the practical capabilities of design of self-diagnosing systems. This is achieved by the use of probability criteria to estimate the effectiveness of self-diagnosing systems, as well as algorithms for synthesis of mutual monitoring models considering both the reliability characteristics of the elements and the sensitivity of the system to their failures. Secondly, the use of an inverse method of coding the states of the elements and results of their testing was significant. The approach allows the creation of analytic methods for determination of sets of permissible system defects by application of rather simple computing methods to find the eigenvectors and values of the test matrices. Figure 1; References 10: 6 Russian, 4 Western.

UDC 681.518.2

Software for Simulation in Diversity Radio Measurement Systems

907K0090B Kiev ELEKTRONNOYE
 MODELIROVANIYE in Russian Vol 11 No 6,
 Nov-Dec 89 (Manuscript received 24 Nov 88; after
 revision 10 Mar 89), pp 68-73

[Article by V. P. Tkachenko, Candidate of Technical Sciences, Kiev Institute of Civil Aviation Engineering]

[Abstract] The author's institute has developed a simulation system for diversity radio measurement systems based on a universal modeling system, designed to perform the following tasks: efficient placement of various classes of diversity systems in a fixed region of space by linear programming and the Monte-Carlo method; analysis of generated system structures; modeling of the interaction of individual subsystems; selection of a group of systems to be used to produce measurement information; modeling of the trajectories of motion and dynamics of moving objects; processing of measurement information both by a user computer system and at the measurement points by dynamic filtration, the method of least squares and recurrent data processing; selection of the proper data processing algorithm according to the composition of the system; modeling of the radio system considering the level of noise present; and modeling of the failures of individual subsystems. The design of the simulation model is discussed. The GASP-IV software package was used to develop the system.

UDC 621.382.3

Noise in Millimetric-Wave Schottky-Barrier Mixer Diodes

907K0081A Kiev IZVESTIYA VYSSHIKH
UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA
in Russian Vol 32, No 10, Oct 89 (manuscript received
9 Nov 88) pp 24-30

[Article by S.A. Kravchuk, T.N. Narytnik, and V.P. Potiyenko]

[Abstract] Mechanisms and characteristics of noise in millimetric-wave Schottky-barrier mixer diodes are reviewed, considering not only the already well covered and understood thermal and shot noise but also the still studied and less understood third kind: excess noise. Generation of this noise has been associated with the transport of majority carriers and with several processes which contribute to the barrier-crossing current and influence the capacitance-voltage characteristic of such a diode. Heating of the electron gas, scattering by small traps in the vicinity of the semiconductor-metal junction, and intervalley scattering have been found to contribute to not only low-frequency ($1/f$) but also high-frequency excess noise. Experimental data on both frequency and current dependence of excess noise as well as the available theoretical and experimental data on effective barrier, excess noise, and diode temperatures pertain essentially to GaAs devices. Figures 3; references 16.

UDC 621.372.65

Performance Characteristics of Detector Diodes in Microwave Controls

907K0081B Kiev IZVESTIYA VYSSHIKH
UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA
in Russian Vol 32, No 10, Oct 89 (manuscript received
26 Dec 88) pp 78-80

[Article by I.V. Lebedev and A.S. Shnitnikov]

[Abstract] Performance characteristics of microwave detector diodes used in devices such as limiters and protective devices are analyzed on the basis of their conventional equivalent-circuit diagram with a p-i-n diode as the d.c. load. The dependence of the shunting resistance $R_{pin,p}$ of the p-i-n diode at microwave frequencies on the d.c. bias current I_0 is described by the fairly accurate relation $R_{pin,p} = K_2 I_0^m$ (constant coefficient K_1 being used in the voltage dependence of current I_0). Accordingly are calculated the loss of microwave power in the detector diode and the output power from the p-i-n diode as functions of the microwave input power. Calculations for detector diodes with 3 pF or 4 pF capacitance indicate the possibility of hysteresis in the power relation, with a jump increase of the output power upon an increase of the input power within a certain range. Figures 5; references 8.

UDC 621.396.622

Hybrid Integrated Circuits for Balanced Shortwave Diode Mixers

907K0081C Kiev IZVESTIYA VYSSHIKH
UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA
in Russian Vol 32, No 10, Oct 89 (manuscript received,
after revision, 2 Nov 88) pp 83-85

[Article by S.A. Kravchuk and Yu.I. Yakimenko]

[Abstract] The feasibility of producing hybrid integrated circuits for balanced shortwave diode mixers with minimum conversion loss, by combining a slotted-waveguide line with a coplanar line and a pendant strip line, was studied and established experimentally with such a structure on a 0.15-0.18 mm thick substrate inside a metal housing. The housing was formed by two segments of a rectangular waveguide joined along their wide edges into a right-angle L-channel carrying the mixer structure in its E-planes. The mixer structure consisted of a unilateral slotted-waveguide line, a smooth transition piece connecting the input end of this line to a waveguide through which signals were fed to it, a nonhomogeneous coplanar carrying planar GaAs Schottky-barrier diodes and feeding heterodyne power to them, a narrow-band Y-joint and a probe-transition between the slotted-waveguide line and the coplanar line, a low-pass filter extracting the intermediate frequency, a slotted quarter-wavelength stub exciting the probe-transition at precisely the heterodyne frequency, and a pendant strip line with a wave impedance of 50 ohms. Measurements yielded a conversion loss of only 4.5-6.5 dB over an at least 17 GHz wide frequency range. They also showed an up to 20 dB decoupling between signal input and heterodyne input to the slotted-waveguide line, but over an only 1-2 GHz wide frequency band characterized by maximum signal voltage standing wave ratio in the absence of heterodyne power. Application of heterodyne power lowered this ratio to 1.1-2.5 within the operating frequency range. Figures 3; references 2.

UDC 621.385.6

Design Calculations for Bunching of Rotating Relativistic Electron Beam

907K0081D Kiev IZVESTIYA VYSSHIKH
UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA
Vol 32, No 10, Oct 89 (manuscript received 30 May 88)
pp 89-90

[Article by D.M. Benevolenskiy and S.M. Movnin]

[Abstract] Bunching of a rotating relativistic electron beam is analyzed theoretically, considering a hollow such beam which propagates along its axis at a nonrelativistic velocity under a sinusoidal voltage across the cavity gap. Integration of the applicable equation of motion yields expressions for both longitudinal and transverse components of the electron momentum at the gap entrance. From the relations between these two

momentum components and the corresponding components of the electron velocity at the gap exit are calculated the velocity modulation index and the bunching parameter so that design and performance analysis can proceed as for a klystron. References 4.

UDC 621.385.6.01

Analytical Wave-Process Estimates for Microwave Vacuum Electron Devices

907K0081E Kiev IZVESTIYA VYSSHIKH
UCHEBNYKH ZAVEDENIY: RADIOELEKTRONIKA
in Russian Vol 32, No 10, Oct 89 (manuscript received
12 Dec 88) pp 90-92

[Article by Yu.L. Bobrovskiy, S.R. Zaremskiy, and
K.N. Kuzyakin]

[Abstract] Analytical design and performance optimization of microwave vacuum electron devices such as

klystrons is considered, a major problem being the inconsistency between estimates based on the "field" description of the wave process and estimates based on the kinematic description of electron bunching in the presence of a large space charge. This inconsistency can be resolved by interpolation of both descriptions so that each retains its intrinsic range of validity and, moreover, adequately accurate universal analytical estimates can be made without an "overtaking" error. The validity limits of both descriptions are, for this purpose, established in terms of angular displacement and current respectively. Displacement is treated in accordance with the Euler wave equation. The current is then treated as a function of both the displacement and the space-charge factor, a \sin^{-1} function of the space-charge factor being the correct approximation of the displacement at which the fundamental component of the high-frequency current has the maximum amplitude. References 5.

UDC 621.316.542-186.2.027.3

Design Features and In-Service Inspection of 1150 kV Air Circuit Breakers

907K0067A Moscow ELEKTROTEKHNIKA in Russian
No 10, Oct 89 (manuscript received 22 Mar 89)
pp 21-25

[Article by V.M. Lavrentyev, engineer, and V.M. Plekhanov, engineer, Planning Department of Long-Distance Electric Power Transmission, USSR Ministry of Power Systems]

[Abstract] The new 1150 kV air circuit breaker features a contact assembly including the arc-quenching mechanisms inside the welded housing tank and resistors with preswitching mechanisms in containers above the tank. The preswitching devices were redesigned in the process of debugging and setting up the prototype, to improve their stability and to provide a mechanism for their regulation. Production units have been broken in and certified for operation on the Ekibastuz-Kokchatov transmission line. The results of subsequent in-service inspection indicate an excellent performance of the preswitching devices, switching overvoltages being reduced to only 1.3 times nominal phase voltage. The pneumatic characteristics of this circuit breaker need to be further studied and evaluated, and the equipment readiness factor needs to be raised. The sectional construction of arc-quenching mechanisms and valves eases substantially disassembly and reassembly for maintenance and replacement purposes. Figures 2; tables 1; references 7.

UDC 621.315.21.3.002.5

Technology and Equipment for Cold Rolling of Multistrand Cable with Ceramic Insulation in Variable-Profile Passes

907K0067C Moscow ELEKTROTEKHNIKA in Russian
No 10, Oct 89 (manuscript received 10 Mar 88)
pp 47-50

[Article by V.V. Nosal, doctor of technical sciences, Yu.V. Rybakov, candidate of technical sciences, V.T. Golovkin, engineer, and M.M. Novokreshchenov, candidate of technical sciences]

[Abstract] A technology has been developed for cold rolling of multi-strand cables with ceramic insulation and steel sheath. Blanks 18 mm in diameter can be rolled down in two passes, to a 7 mm intermediate diameter and then down to any diameter not smaller than 3 mm, in a PPTK-15 mill. Blanks 3 mm in diameter can be rolled to any diameter not smaller than 1 mm in a single pass in a KhPT-3 mill. Both mills are modifications of the KhPTR-type industrial tube mill, the 13.5 kW PPTK-15 mill for rolling more rigid large-diameter cables and the 4.5 kW KhPT-3 mill for rolling less rigid small-diameter cables. They produce cables with stepped

diameter of any required length, typically for thermoelectric instrument transducers. The rolls are respectively 180 mm and 61 mm in diameter. The larger mill contains a cage, an A02-72/8/6/4 380 V induction motor as main drive, a rod-and-crank mechanism, a blank feed-and-rotation mechanism, a feeder chuck with a quick-return mechanism, a pickup chuck, and a lubrication mechanism using oil as lubricant-coolant. The smaller mill contains a working cage with two rolls, an A063 12/8/6/4 380 V induction motor as main drive, a rod-and-crank mechanism with a speed reducer, a coil unwind-and-feed mechanism, a feeder chuck with a quick-return mechanism, and a lubrication system using an emulsion as lubricant-coolant. The equipment was tested on cables with MgO insulation and 12Cr18Ni10Ti stainless steel or CrNi78Ti alloy sheath for Chromel and Alumel thermocouples, the purpose being to determine the optimum process. Heat treatment at 900-1100°C was found to be necessary after each, also the necessary blank sizes and roll pressures were determined, to ensure cable size and shape remain within tolerance limits. The results of microhardness tests and metallographic microstructural examination indicate excellent mechanical characteristics of cables produced by this cold rolling process, namely high plasticity of the conductor strands and high strength of the sheaths. Figures 2.

UDC 621.311.6:629.113.6].001.4

Ni-Zn Energy Sources for Electric Cars: Prospects of Improving Their Characteristics

907K0067E Moscow ELEKTROTEKHNIKA in Russian
No 10, Oct 89 (manuscript received 16 Jun 87) pp 65-68

[Article by V.Ye. Dmitrenko, doctor of technical sciences, professor, V.V. Berendt, candidate of technical sciences, T.V. Balashova, candidate of chemical sciences, and A.Yu. Latunina, candidate of technical sciences]

[Abstract] The performance characteristics of Ni-Zn batteries as possible energy sources for electric vehicles are evaluated by regression analysis on the basis of a full 2^3 -factorial experiment using laboratory and field test data. Thus are established the dependence of discharge capacity and discharge voltage on the percentage charge level, on the discharge current, on the ambient temperature, and on the number of discharge-recharge cycles, and the dependence of battery life in terms of the number of available discharge-recharge cycles on the percentage discharge depth. The evaluation confirms that Ni-Zn batteries may become viable energy sources for electric vehicles in their present stage of development, under a thermally favorable conditions of service and with the discharge not exceeding 80%. Figures 6; references 5.

UDC 621.391.26

Space-Time Characteristics of Optical Signals in Raster-Type Data Transmission Systems

907K0035A Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 5, May 89

(manuscript received 19 Apr 88) pp 4-6

[Article by R.B. Shemshedinov and T.F. Kharisov]

[Abstract] Modulation of a coherent Gaussian light by a raster in the form of a transparent strip is considered, this strip moving as the position of the optical receiver relative to the light source changes. The space-time characteristics of the thus generated data transmitting optical signal are analyzed, assuming that the raster constitutes a window of a given width in an opaque shield in a plane (XOY) perpendicular to the axis (Z) of the light beam and moves along one axis (X) in this plane. The photodetector, located at a given distance behind the raster and oriented parallel to it, is assumed to have zero lag. The normalized amplitude distribution over the detector plane is, on this basis, described by a Fresnel surface integral. The instantaneous light intensity distribution at various instants of time and the changes of light intensity at various locations as function of time are calculated accordingly by numerical integration, upon introduction of a diffraction parameter. Figures 4; references 5.

UDC 535.317.1:535.317.6

Law of Sines for Aperture Synthesis

907K0035B Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 5, May 89

(manuscript received 15 Aug 88) pp 19-21

[Article by V.A. Zverev]

[Abstract] An optical system which consists of several telescoping stages and a focusing stage behind them is considered for aperture synthesis. The optical axes of all stages are parallel to one another and the focusing stage is coupled to the last telescoping one through two parallel plane mirrors, each slanted at a 45° angle to the respective optical axis. The condition under which a light beam will form an image of an off-axis object point in such a system is established in terms of angles between the two wavefronts at respectively the entrance to and the exit from each stage. This condition relates the ratio of the sines of the two angle to other parameters, geometrical ones and the refractive index, of the system. This ratio is calculated first generally and then for a Mersenne telescope, either with the entrance pupil on a concave reflecting surface or with the exit pupil on a convex reflecting surface. Figures 1; references 5.

UDC 535.241.13:535.51

Polarization Modulator

907K0035D Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 5, May 89

(manuscript received 4 Jul 88) pp 27-28

[Article by V.N. Polyakov and V.K. Rezunkov]

[Abstract] The experimentally established feasibility of using an attenuated-total-reflectance polarization modulator with controllable microlayer for controlling the polarization of light, namely its azimuth and ellipsoidality, is validated theoretically on a multilayer dielectric mirror. Such a modulator consists of a microlayer with adjustable optical thickness coating a dielectric substrate and a layer underneath that substrate which controls the microlayer thickness by a conversion mechanism, this multilayer stack being placed in a dielectric "cup" and covered with a right equilateral triangular prism-"roof" touching the cup around its rim. The performance analysis of such a modulator is based on the applicable Fresnel equation. Thermal drift of the microlayer thickness can be minimized by matching that microlayer and its substrate with cup, each made of a different material, with respect to linear thermal expansion. Figures 3; references 4.

UDC 535.317:621.383

Algorithm of Correlational Image Analysis for Automatic Focusing of Camera Objective

907K0035E Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 5, May 89

(manuscript received 4 Jul 88) pp 32-34

[Article by R.B. Mitkin]

[Abstract] An algorithm of image analysis for automatic focusing of the camera objective is proposed which involves direct comparison of images in the rangefinder channels by multiplicative superposition, rather than by their conversion into a sequence of discrete electric signals and subsequent processing of the latter as is done in the Elikon Avtofokuss camera. The algorithm of such an analyzer is designed for a heuristic program of automatic focusing, a program which consists of both functional and corrective parts. Automatic focusing involves essentially formation of optical images in channels of the triangulation system, orientation of images relative to one another, and generation of control signals for the mechanism which moves the objective. Assuming that the fields of two-dimensional images are statistically stationary in time, determining their relative displacements reduces to maximizing the applicable correlation function R equal to a surface integral. In order to increase the signal-to-noise ratio, it is preferable to use a correlation algorithm which involves comparison of images with inverted contrasts. Optically controllable

transparencies on MOS-LC (metal-oxide-semiconductor and liquid crystal) structures can be used for either dioptric or catoptric recording of the R^* function, $R^* - R$ being the function which correlates direct and inverted images. Figures 3; references 6. direct and inverted images.

UDC 535.51:778.38

Measurement of Optical Vector Field Characteristics by 'Polarization Interferometry'

907K0094A Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 11, Nov 89

(manuscript received 9 Aug 89) pp 3-5

[Article by A.L. Volpov and Yu.A. Zimin]

[Abstract] Polarization interferometry is proposed for recording optical vector field scattered by remote objects, this requiring that displacement interferograms be recorded in a medium which gives a vectorial response and be reconstructed by means of coherent light with a different polarization. Measurement of the luminance distribution over the reconstructed field is then done through variously oriented polarization filters. The mathematical algorithms of these steps yield a reconstructed field which corresponds to the original one exactly, except for a constant phase shift, just as a reconstructed optical scalar field reconstructed from an interferogram corresponds to the original one. Comparative analysis and quantitative estimates indicate that this method is much more sensitive, by up to ten orders of magnitude, than polarization holography. The advantage reduces to seven orders of magnitude, inasmuch as 1000 holograms exposed for 1 μ s can be recorded and reconstructed within the same 1 ms. References 7.

UDC 535.345.675

Spectral Characteristics of Two Solc Filter Variants

907K0094B Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 11, Nov 89

(manuscript received 28 Sep 88) pp 5-7

[Article by T.A. Vinogradova and A.A. Sidorenko]

[Abstract] Two variants of the Solc polarization-interference filter, only two polarizer plates and thus fewer than in a Lyot filter separated by a stack of birefringent plates of the same thickness and the same crystalline material, are evaluated comparatively in terms of their transmission spectra. In the first variant one of the principal optical axis in all plates makes the same angle with the plane of transmission in the front polarizer, this angle being however read to the right in the odd-numbered plates and to the left in the even-numbered plates, while the front polarizer and the back polarizer are oriented with their planes of transmission

mutually orthogonal. The number of secondary peaks in the transmission spectrum of this variant is always even, with any number of birefringent plates, their number increasing by two as another plate is added. When the number of plates is odd, then the central peak splits into two which are narrower than all the lateral ones. When the number of plates is even, then the structurization of secondary peaks is analogous that for an equivalent Lyot filter. In the second variant the optical axis of each succeeding birefringent plate is shifted by the same angle relative to that of the preceding one, all being shifted either to the right or to the left, while the two polarizers are oriented with their planes of transmission parallel to one another. The number of secondary peaks in the transmission spectrum of this variant depends largely on the number of birefringent plates and is equal to that number minus 1. The sequence of these peaks is characterized by an asymptotically decreasing magnitude. It applies to both variants that the kind of series which successive secondary-peak intensity ratios $I_{si}/I_{s(i+1)}$ form depends largely on the number of birefringent plates and is very different then for a Lyot filter. Figures 2; references 7.

UDC 621.47:535.311

Synthesis of Mirror-Type Radiation Energy Concentrators

907K0094C Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 11, Nov 89

(manuscript received 10 Nov 88) pp 17-19

[Article by R.A. Zakhidov]

[Abstract] Synthesis of mirror-type radiation energy concentrators for achieving radiation power densities up to 10 MW/m² is considered, assuming that some optical and geometrical characteristics of both radiation source and radiation receiver are known while also taking into account physical influencing factors. The problem is formulated for axisymmetric reflecting surfaces, paraboloidal ones being most practical and effective, assuming a known luminance distribution over the radiation source and a known geometry of the radiation receiver-mirror. The problem is formulated as a variational inverse one for the optimum mirror generatrix as a function of the base radius $f(r)$ minimizing the difference ideal and real illuminance distributions over the mirror surface. The target function $f(r)$ is approximated with a polynomial one so that its optimization is reduced to optimization of the vector of polynomial coefficients. The algorithm of the solution is constructed for execution completely "by hand" or completely on a computer, also by switching from either one to the other in the calculation process. Figures 2; references 4.

UDC 535.317

Transformation of Gaussian Beam by Means of Circular Centered Diaphragm

907K0094D Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 11, Nov 89

(manuscript received 24 Nov 88) pp 19-21

[Article by S.I. Molkov and T.V. Shelyakova]

[Abstract] Transformation of a Gaussian radiation beam by means of a circular diaphragm is considered, a real Gaussian beam being replaced with a Gaussian one of equal axial intensity in the far field. The transformation is done by the matrix method, which can be extended to beams with radii larger than half the radius of the diaphragm. The algorithm is demonstrated on a diaphragm with sharp edges and coaxial with the beam. One element in the 2×2 square transformation matrix is determined by parameters of the incident beam, the element on the same diagonal being zero and the two elements of the other diagonal 1. The parameters of the exiting beam are determined from that condition of equivalence. The problem of determining its parameters in the near field being solvable numerically by the Galerkin approximation method. Figures 3; references 3.

UDC 681.7.001.24:65.011.56

Computer-Aided Design of Technological Processes for Manufacture of Optical Elements

907K0094E Leningrad

OPTIKO-MEKHANICHESKAYA

PROMYSHLENNOST in Russian No 11, Nov 89

(manuscript received 4 Jan 89) pp 36-37

[Article by S.I. Lelyukhin and A.V. Yegorov]

[Abstract] A system covering computer-aided design of technological processes for manufacture of optical elements has been devised, the principal stage of the design process being planning the sequence of operations and selecting the necessary equipment. This stage, preceded by preparation of the input data, includes design of tools and search for matching standard fixtures. This stage is followed by identification and listing of all auxiliary materials, design and standardization of the modes of equipment operation, specification of the optical glass for purchase, and documentation of the output data. Design calculations include cost analysis and financial forecasts based on production data. Each stage of the design process is handled by a separate assigned subsystem, data exchange between them being effected by way of file sharing. The design system has provisions for data base management and editing the technological processes. The design system operates in the interactive mode with time division of routine operations so that different specialists with different skills can participate in its management. All subsystems can have their software simultaneously but independently debugged and new subsystems can be easily added. Only a small random access memory is required for this system so that an SM1420 or DVK minicomputer with a 256 kbyte RAM and an RT-11 (NTS, RAF) operating system is adequate. Figures 1; references 1.

UDC 621.382.002

Optimization Method of Simulating Electron-Beam Lithography Processes

907K0085A Moscow MIKROELEKTRONIKA
in Russian Vol 18, No 6, Nov-Dec 89 (manuscript
received 6 Feb 89) pp 483-496

[Article by K.A. Valiyev, A.N. Kirillov, B.N. Kovtun, A.V. Lebedeva, and T.M. Makhviladze, Institute of Engineering Physics, USSR Academy of Sciences]

[Abstract] A critical review of conventional methods of correcting for proximity effects in electron-beam lithography, particularly M. Parikh's and P.D. Gerber's methods and Fourier analysis of the "latent" image, has revealed three principal deficiencies of each: 1) no effective monitoring of energy density and its gradient at points along the edges of the resist, 2) incomplete formalization of correction algorithms, 3) technological non-optimality of solutions to the correction problem regarding the "latent" image. An adequate formulation of the correction problem is, therefore, proposed so that the problem reduces to optimal determination of exposure doses which will minimize the given target function under given constraints on their magnitude. The problem is solved accordingly by the method of minimum phonon fog under conventional constraints. The entire set of exposure parameters can thus be optimized in a broader than conventional scope, as long as adequate optimality criteria have been established and algorithms designed for computer time economy are available. The method is demonstrated on computer-aided insulation layout and is extended so as to also cover the resist development stage. Figures 6; references 16.

UDC 621.793.16

Prospects of Using Method of Laser Pyrolysis for Fabrication of Micro- electronic Structures and Status of Its Development

907K0085B Moscow MIKROELEKTRONIKA
in Russian Vol 18, No 6, Nov-Dec 89 (manuscript
received 17 Nov 88) pp 497-507

[Article by L.A. Ryabova, V.S. Salun, and I.Ye. Reshetnikov, Institute of Radio Engineering and Electronics, USSR Academy of Sciences]

[Abstract] Use of a laser beam for triggering chemical decomposition of organometallic compounds having been proposed by G.A. Domrachev in 1977, its use for fabrication of microelectronic structures has since then been considered on account of its highly localized heating effect and its high spatial resolution. Visible and infrared lasers are most suitable for this application, inasmuch as decomposition of gaseous organometallic and organo- silicon compounds by them involves purely or predominantly thermal mechanism rather than photochemical mechanisms alone. A general description of the laser pyrolysis process and of the equipment for

experimental deposition of microstructures on substrates is given, Ar^+ , Kr^+ , and CO_2 -lasers having so far been used for deposition of semi-conductor (Si, GaAs, InGaAs, GaAsP) films, Si bars, graphite films and bars, metal (Fe, Ni, Cu, Pd, W, Au) films, and dielectric (SiC , SiO_2 , Si_3N_4) films from suitable organic compounds of Si (silanes), Ga, In, Fe, Ni, Cu, Pd, W, Au respectively: alone or mixed with appropriate inorganic compounds (hydrocarbons alone for deposition of graphite films and bars). Theoretical analysis of the microstructure buildup mechanism is on the kinetics of laser-pyrolysis with attendant substrate heating and on the kinetics of film nucleation in accordance with available research data, nonlinear effects having also been taken into account. This method has also been used for making metal, low-resistivity silicon, or metal silicide (TiSi) interconnections for fabrication or integrated-circuit up to VLSI systems. The authors thank Yu.D. Kalafati and I.A. Serbinov for helpful discussions. Figures 4; references 67.

UDC 681.324:681.332/333

Accelerator Hardware for Faster Modeling of VLSI Circuits

907K0085D Moscow MIKROELEKTRONIKA
in Russian Vol 18, No 6, Nov-Dec 89 (manuscript
received 10 Feb 88) pp 554-560

[Article by B.G. Sergeyev, Institute of Electronic Control Machines, Moscow Scientific-Industrial Association 'Elektronmash' (Electronic Machines)]

[Abstract] Acceleration of computer-aided VLSI modeling is considered, namely event-timing conveyorization of the modeling algorithms at both logic level with diodes and switching level with transistors. Inasmuch as the effectiveness of conveyorization depends on certain conveyor characteristics such as mean output branching coefficient and productivity, the latter measured in events per second, these characteristics are evaluated for a synchronous conveyor using the concepts of linearity and continuity. The optimum algorithm is readily constructed for binary modeling only, disregarding intrinsic time delays in circuit elements. For modeling in a polysymbolic alphabet (0, 1, high-impedance state Z, indeterminate state X) is therefore constructed an only close to optimum algorithm. This 10-step algorithm does not satisfy the continuity condition, because the results of its last step can be used in the much earlier second step. The modular multiprocessor modeling complex developed for this application can contain up to 15 diode modeling processors and contains a processor which executes data exchange between them and with the main CAD system computer, a high-performance general-purpose one. References 4.

65

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